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S.No.	Number of books and chapters in edited volumes / books published per teacher	Page No.
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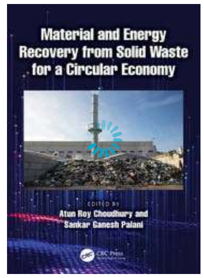

Appraising the Natural Bio-Processes over Thermal Treatments to Treat Municipal Solid Waste

A Step Toward a More Sustainable Environment

By Arumugam Poornima (/search?contributorName=Arumugam Poornima&contributorRole=author&redirectFromPDP=true&context=), Subramani Yashini Vidhya (/search?contributorName=Subramani Yashini Vidhya&contributorRole=author&redirectFromPDP=true&context=), Kanagaraj Suganya (/search?contributorName=Kanagaraj Suganya&contributorRole=author&redirectFromPDP=true&context=), Balraj Sudha (/search?contributorName=Balraj Sudha&contributorRole=author&redirectFromPDP=true&context=), Sundaravadivelu Sumathi (/search?contributorName=Sundaravadivelu Sumathi&contributorRole=author&redirectFromPDP=true&context=),
Sanjeeb Kumar Mandal (/search?contributorName=Sanjeeb Kumar Mandal&contributorRole=author&redirectFromPDP=true&context=) (https://orcid.org/0000-0002-3920-9456)
, Sumithra Salla (/search?contributorName=Sumithra Salla&contributorRole=author&redirectFromPDP=true&context=)

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ABSTRACT

Conventional environmental management and waste treatment technologies have shown significant advancements in recent times. “Waste” is no longer waste these days but has become one of the significant sources to generate tonnes of energy in different forms such as heat, fuels, and electricity. In that regard, municipal solid wastes comprising relatively more of degradable organic fractions than non-degradable wastes fall under one major category that drives toward energy plants. Management strategies had evolved with time, wherein burning of waste started fading while biological treatments are attracting more attention in order to bring the discipline of “Waste to energy” with less harm to the environment. Thermal treatments played effective roles in waste management but their harmful emissions became another concern in terms of environmental pollution. Though it cannot be completely replaced by another eco-friendly alternative, a unified solid waste managing system with controlled discharge of hazardous components and incorporation of biological processes to treat municipal solid wastes can serve well in reducing the dependence on more hazardous ways to degrade wastes. Additionally, recent research has demonstrated that some bacteria are capable of breaking down even non-biodegradable plastics. On that note, the following chapter focuses on the comparative assessment of both the thermal and biological treatments of municipal solid waste to energy plants, highlighting the significance of biological strategies, thus stepping toward a less toxic and more sustainable environment.

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NAVIGATING THE H□RI□□N: E□PL□RING FUTURISTIC TRENDS IN PHARMACEUTICALS AND DRUG DELIVERY SYSTEMS

Abstract

The pharmaceutical sector has seen tremendous improvements in medication delivery technologies in recent years. These cutting-edge innovations, which range from tailored medicines to nanotechnology-based solutions, are transforming pharmaceutical administration and improving its efficacy. This chapter explores how innovations in personalized medicine, nanotechnology, and novel medication delivery methods are altering the precise treatment of disease. The emphasis is made on how innovation and focused interventions are reshaping the healthcare scene and creating a bright future. From ancient herbal medicines to contemporary drug development procedures, the story develops with the advancement of pharmaceutical science. The complexity of diseases, the rising cost of medication research, and the incorporation of cutting-edge technologies like AI-driven drug design, 3D printing, and nanotechnology are some of the elements driving this progression. Additionally, it examines how regulatory actions, rising technology, and the Industry 4.0 revolution have affected pharmaceutical modernization efforts. Biopharmaceuticals, mRNA vaccines, 3D printing, nanotechnology, AI-driven drug development, and smart drug delivery systems are among the upcoming trends that are being investigated. This thorough viewpoint offers insights into the changing pharmaceutical industry, as well as the opportunities and difficulties it poses. The present chapter explores pharmaceutical trends: evolving technology, advanced drug delivery, biopharmaceuticals, 3D printing,

Authors

Dr. Sumithra Salla
Assistant Professor
Department of Biotechnology
Chaitanya Bharathi Institute of Technology
Hyderabad, Telangana, India.
sumithra.chem@gmail.com

□yothika Meenakshi Kambhampati

Divyamshu Surabhhi

Chaitra Gali

Chunduru Sai Hari Hara Sudheshna

Sanjeeb Kumar Mandal

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nanotechnology, AI in drug discovery, and smart delivery systems, providing insights into the future landscape and challenges.

Keywords: Artificial intelligence, Internet of Technology, 3D-printing, Monoclonal Antibodies

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I. INTR□DUCTI□N T□ FUTURISTIC TRENDS IN PHARMA AND DRUG DELIVERY

Emphasizing the vital role of the pharmaceutical industry, this chapter explores groundbreaking trends in drug delivery systems. These advances, spanning personalized medicine to nanotechnology, are revolutionizing disease treatment with enhanced precision. The broadening array of drug delivery techniques, encompassing implants and gene-based therapies, holds the potential for elevated patient outcomes. The evolving healthcare panorama is characterized by innovation and targeted interventions, shaping a promising future.

1. **Evolution of Pharmaceutical Technology:** The pharmaceutical industry stands as a pivotal and swiftly advancing sector globally. With its role encompassing the creation and manufacturing of remedies addressing a spectrum of ailments, from everyday illnesses to life-threatening conditions, the industry's evolution has been remarkable. From its inception to the present day, the industry has consistently pushed the boundaries of innovation to enhance the entire drug development process, encompassing formulation, production, and delivery.

   Embedded within the pharmaceutical sciences, pharmaceutical technology pertains to the intricate domains of drug composition, formulation, preparation, manufacturing, and quality control for both custom-prepared and commercially produced medications. It encompasses the multifaceted processes that underpin the creation of pharmaceuticals, optimizing their effectiveness and safety. This facet of the industry harmonizes with the overarching goal of refining treatment methodologies, ensuring that the drugs developed offer maximum therapeutic value while minimizing potential risks(Pharmaceutical Technology Core Concepts - Czech Pharmaceutical Society, n.d.).The pharmaceutical industry, a rapidly evolving cornerstone of modern society, traces its roots to an age where the journey of drug discovery was influenced by the relentless pursuit of overcoming illnesses. People's keen observations and recognition of a plant's healing properties, often through trial and error, played a pivotal role in this process.These traditional methods, an interplay of ancient wisdom and practicality, formed the foundation upon which the industry now stands(Sumner, 2001).

   Addressing the discovery of aspirin as a historical example for early pharmaceutics, the story of the willow tree (*Salix* sp.) unfolds across the annals of time, etched in clay tablets and historical accounts(Wells, 2003). The narrative of aspirin's lineage extends back over 3500 years. In ancient times, willow bark's pain-relieving properties remained unknown to the Sumerians and Egyptians who employed it, with salicin, its active agent, forming the bedrock for aspirin's eventual discovery (Lévesque & Lafont, 2000; Desborough & Keeling, 2017; Montinari et al., 2019). Willow leaves were used to treat a variety of diseases in Assyrian records from the Sumerian era (3500-2000 BC). Similarly, the Babylonians used willow tree extracts to treat fever, discomfort, and inflammation. This botanical heritage continued, with the Greek physician Dioscorides advocating willow bark for inflammation reduction, a practice that merged plant properties with medical wisdom to illuminate an early instance of pharmaceutics, healthcare, and drug development (Chevallier, 1996; King, 1974; Burns &Fulder, 2002).

As centuries marched forward, the historical curtain rises on the 18th century, initiating the modern era of aspirin discovery. The story of aspirin, now one of the most widely used drugs worldwide, begins with its birth in 1897. The evidence of willow bark's analgesic use emerged in 1862 through artifacts that dated back to the 1500BC, one of them currently known as the Edwin Smith Surgical Papyrus and the other one called Ebers Papyrus, detailing ancient herbal remedies and the use of salix (willow) for pain relief(Bryan, 2021). Through the rise and fall of empires, willow bark's healing attributes persisted, endorsed by eminent figures like Hippocrates and Pliny the Elder(Lévesque &Lafont, 2000; Lichterman & Diarmuid, 2004; Desborough & Keeling, 2017; Montinari et al., 2019).The advancement of natural remedies gained momentum with the revelation of the fever-relieving properties of cinchona bark. Reverend Edward Stone, in 1763, investigated the use of willow bark, laying the foundation for its potential in treating fevers(Stone, 1763). The journey continued with pioneers such as Johann Buchner and Pierre-Joseph Leroux refining willow bark into crystalline forms, eventually leading to the isolation of salicylic acid. The journey culminated in 1897 when chemist Felix Hoffmann synthesized aspirin, a significant stride toward modern medicine(Lévesque &Lafont, 2000, Desborough & Keeling, 2017 and Montinari et al., 2019). This historical narrative bridges the past with the present, revealing the inception of pharmaceutical technology.

From these historical origins, the pharmaceutical industry emerged as an agent of transformation. Rooted in large-scale production of drugs, including organic chemicals and dyes, the industry's impetus gained traction post-World Wars. A pivotal shift in global perspective saw the recognition that technological progress could eclipse the devastation wrought by conflicts. The potential to heal and restore lives through innovative compounds became evident, spurring the establishment of enterprises dedicated to concocting remedies for injuries and diseases caused by pathogenic microorganisms.This fervent pursuit of improvement aligned with nations' aspirations to elevate their standing and enhance life expectancy. The quest for novel compounds designed to combat ailments became an emblem of progress. The historical thread woven through the discovery of aspirin and the evolution of pharmaceutical technology merges seamlessly with this narrative, forging a continuum of innovation that reverberates through the ages. The exploration of historical remedies and the evolution of modern pharmaceuticals converge to illuminate a tapestry of progress, fueled by the indomitable human drive to conquer challenges and elevate the well-being of societies worldwide (Malerba & Orsenigo, 2015). In this intriguing tapestry of history and innovation, the pharmaceutical industry emerges as an ever-evolving force, propelled by the legacy of the past and the inexorable drive to enhance human well-being.

2. **Need for Advancement in Pharmaceutical Technology:** The pharmaceutical industry has been an instrumental force in enhancing global well-being over the last several decades, contributing significantly to increased life expectancy and the stability of healthcare systems (IFPMA, 2022). As the industry continues to evolve, driven by a multitude of factors, its pivotal role in both healthcare and the global economy becomes increasingly evident. This dynamic evolution is underscored by the constant push for innovation and modernization, shaping a landscape characterized by groundbreaking technologies and novel approaches to drug development, manufacturing, and delivery.

One of the foremost drivers propelling the evolution of the pharmaceutical industry is the escalating complexity of diseases. The ever-deepening understanding of the molecular underpinnings of various ailments has empowered scientists to develop treatments with enhanced precision and efficacy. Personalized, targeted medications have emerged, diverging from the conventional approach (Schmidt et al., 2020).

The escalating costs associated with drug development further fuel the industry's transformation (IFPMA, 2022). With the price tag of bringing a new drug to market soaring into the billions, pharmaceutical companies are compelled to explore innovative avenues to mitigate expenses (Destro and Barolo, 2022). This financial pressure has catalyzed a quest for cost-reduction strategies throughout the drug development lifecycle, from research and discovery to manufacturing and distribution. The industry's financial landscape has also led to a shift in focus towards diversification and the pursuit of new revenue streams.

The integration of advanced technologies defines the modernization of the pharmaceutical industry. Innovations like AI-driven drug design and 3D printing streamline drug discovery and delivery. Deep learning expedites drug repurposing, using patterns to uncover molecular relationships, enhancing efficiency (Nag et al., 2022; Pan et al., 2022). 3D printing aids personalized medicine by creating drugs for specific patients, particularly in hospital settings (Wang et al., 2023). Nanotechnology transforms drug delivery, with nanoparticles targeting cancer cells, minimizing side effects. Despite challenges, nanoparticles hold promise for cancer treatment (Tracey et al., 2021; Waheed et al., 2022). In summary, these innovations reshape pharmaceuticals, delivering precise treatments for enhanced patient outcomes.

Undoubtedly, COVID-19 spotlighted the pharmaceutical industry's agility and innovation. Swift vaccine and treatment development showcased its adaptability under duress. This crisis spurred remote marketing, while research focus shifted to COVID-19 treatments. Long-term impacts include approval delays for non-COVID drugs and supply chain disruptions, fostering self-sufficiency. Economic downturn might slow growth, with ethical concerns emerging in increased clinical research. Altered consumption habits due to hygiene practices and telemedicine's rise are transforming healthcare delivery. This response demonstrates the industry's resilience and adaptability, heralding shifts from production to healthcare in response to global challenges (Ayati et al., 2020).

The Industry 4.0 revolution has emerged as a revolutionary force in this setting. This change in thinking entails the digitization and automation of processes, aiming for autonomous decision-making through algorithmic operations. Industry 4.0 not only streamlines operations and reduces costs but also aligns with regulatory objectives for improved quality assurance and faster time-to-market (Destro & Barolo, 2022).

Moreover, the pharmaceutical sector is influenced by an intricate interplay of regulatory initiatives. The foundation for modernisation efforts is laid by current good manufacturing practices (cGMPs), process analytical technology (PAT), and quality by design (QbD). As the industry adopts these frameworks, emerging technologies like continuous processing, closed-loop control, and mathematical modeling are poised to redefine pharmaceutical development and manufacturing (Destro and Barolo, 2022).

This chapter delves into future trends in pharmaceuticals and drug delivery. It examines the evolution of pharmaceutical technology and the need for advanced drug delivery methods. The text explores biopharmaceuticals like monoclonal antibodies and mRNA vaccines, as well as 3D printing for personalized medicine. Nanotechnology's impact on drug delivery, AI and machine learning in drug discovery, as well as intelligent drug delivery systems are discussed. The chapter concludes with insights into the future landscape and challenges of drug delivery, offering a comprehensive view of the evolving pharmaceutical field.

II. BIOPHARMACEUTICALS AND NOVEL THERAPEUTIC MODALITIES

Biopharmaceuticals are a class of pharmaceutical goods that include any biological product created by or from living organisms utilizing recombinant DNA technology, such as therapeutic proteins, vaccines, and cellular and gene therapies. More than 300 Biopharmaceutical drugs have entered the market in the last 40 years. According to a recent analysis on the utilization of the many accelerated medication development and review programs provided by the US Food and medication Administration (FDA) between 2008 and 2021, 97 of 139 (70%) approved biologic drugs used one or more expedited programs (Schaefer et al, 2023). These products' biological origins can offer novel mechanisms of action for treating a range of indications (such as cancers, autoimmune diseases, genetic disorders, or infectious diseases), and the therapeutic recombinant proteins that are currently commercially available range from hormones and growth factors to interferons and enzymes (Szkodny et al, 2022).

1. **Monoclonal Antibodies and their Applications:** A novel family of drugs known as monoclonal antibodies (mAbs) binds extremely precise targets or receptors.The development of mAbs with novel biological properties, such as humanized, chimeric, or murine, as well as the widely utilized hydrodoma method, represents a significant medical advancement and has the potential to greatly improve disease management.

Figure 1: Applications of Monoclonal Antibodies (Ansar & Ghosh, 2013; Mahmuda et al, 2017)

A popular methodology for creating therapeutic antibodies from nonhuman origins is the hybridoma technique. In this method, immortal myeloma cells are fused with B lymphocytes that have been isolated from mice who have received an antigen vaccination. Antigen-specific mAbs are produced by hybridoma cells, however fusion efficiency can be poor and nonhuman mAbs may have negative downstream effects (Mokhtary et al., 2022). Peter M. Bowers and colleagues developed a novel method for collecting and producing human antibodies by combining in vitro somatic hypermutation (SHM) and mammalian cell display. SHM is reliant on the B cell-specific enzyme activation-induced cytidine deaminase (AID), which can be produced as recombinant AID in non-B cells. This method allows for direct antibody selection and full-length, glycosylated IgG maturation. This technique has been used on lines of human B cell lymphoma (Chaudhuri et al., 2004).

For a variety of scientific and therapeutic applications, monoclonal antibodies that target carbohydrate chains (glycans) are essential. Glycans are crucial for cellular functions such as protein folding, adhesion, and signaling. Anti-glycan antibodies are necessary for identifying and comprehending their biological functions. For studying current anti-glycan mAbs and finding novel ones, glycan microarrays are useful tools. However, there is little unified data on the majority of anti-glycan mAbs. This problem is addressed by the Database of Anti-Glycan Reagents (DAGR) and GlycoEpitope, which offer details on current anti-glycan mAbs, including targets and sources. Anti-glycan mAbs that are more advanced, superior, and varied are still needed. The discipline would benefit greatly from a comprehensive, searchable database of anti-glycan mAb sequences (Gillmann et al., 2023).

Changes in the biomarkers of the MAB targets and subsequent processes support the effects of anti-amyloid MABs on the underlying neurobiological mechanisms of Alzheimer's Disease (AD). The FDA has approved two anti-amyloid monoclonal antibodies for the treatment of Alzheimer's disease (AD), lecanemab and aducanumab. These treatments are the first disease-modifying drugs to delay clinical deterioration by interfering with the illness's fundamental molecular processes. These ground-breaking medications can halt the development of severe cognitive impairment due to AD (Cummings et al., 2023).

2. **mRNA Vaccines and Gene-Based Therapies:** In order to alter a protein's expression or cause other recognizable changes, therapeutic genetic material is delivered to a target tissue during gene therapy. While germline or somatic cells can be employed for gene therapy, somatic cells have been the focus of the majority of studies and medication development.

   mRNA vaccines have been developed for several disorders, such as infectious diseases and specific cancer vaccines. The COVID-19 vaccines developed by Pfizer-BioNTech and Moderna are two significant examples of how the COVID-19 pandemic has propelled research toward mRNA vaccines for infectious diseases. The FDA approved the first two SARS-CoV-2 mRNA vaccines in 2020. Both vaccines were developed as LNPs that encapsulated mRNA with ionizable lipids. Among the other mRNA vaccines for infectious diseases now being developed is an LNP-based vaccination based on influenza A and B viruses that encode hemagglutinin antigens. The goal of mRNA cancer

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vaccines is to boost cellular immunity by targeting tumor antigens. The BNT112 and BNT113 vaccines, which are tailored to certain individual mutations, and the FixVac BNT111 vaccine, aimed at four melanoma TAAs, are two examples. For the treatment of different cancers, the safety, tolerability, and effectiveness of the BNT122 combination vaccination are currently being examined (Fayez et al., 2023).

As a result of advancements in cancer biology, over 40% of cancer patients may experience a better quality of life thanks to monoclonal antibodies that can treat a variety of tumors more quickly and affordably. This study is regarding CAR-T cell therapy, a cell gene therapy that employs a chimeric antigen receptor to make a monoclonal antibody, CAR. Patients' T cells are taken out and modified so that they will attach to the cancer cell antigen CD19 and kill it. Despite being FDA-approved, it is not very popular (Srirapu et al., 2023).

Due to its modular architecture, effectiveness, and adaptation to novel viruses, inhalable mRNA vaccines provide shelf-stable, long-lasting protection against respiratory diseases. To address specific translational issues in the lung formulation and delivery environment, Next-generation mRNA vaccine combinations will be developed to make use Polymer and lipid extracts, along with next-generation pulmonary prediction algorithms, were studied. The mucosal immune system and pulmonary epithelial tissues can directly be reached by aerosolized vaccinations, but the respiratory tract has Physical, chemical, and biological barriers that prohibit particles from moving. Extracts with a high molecular weight, are hydrophobic, and/or have a ring-stacking structure, whereas non-interactive coatings prevent aggregation. The efficiency of mRNA is increased and endosomal escape is facilitated by adjusting the particle's pKa values to the pH of the endosome. Predictive evaluation of innovative aerosol therapies will improve with the use of advanced multiscale and ALI models of pulmonary barriers (Roh et al., 2022).

Endogenous genes called miRNAs are essential for cell proliferation, differentiation, and survival. Disease onset and progression are strongly influenced by abnormal miRNA expression and function. The aging population may benefit from treatment for neurological illnesses due to gene therapy, an increasingly potent technology. AAV was used in ALS gene therapy study by Foust et al., which greatly slowed the course of the illness and increased survival time. Successful gene therapy research in preclinical models and clinical trials are now possible via improvements in vector design and delivery technologies that have made it easier to target the brain and spinal cord (Foust et al., 2013; Liu et al., 2022).

Due to its ease of use, low cost, and great efficiency, CRISPR/Cas9 has swiftly emerged as the preferred gene-editing method globally. consists of a Cas9 nuclease, which creates a double-stranded break (DSB), and a guide RNA (gRNA), which locates the loci of interest within the genome. gRNA sequence specificity affects the sensitivity and specificity of CRISPR/Cas9. New Cas9 variants and modified guide RNAs enhance on-target activity, minimize off-target effects, and provide long-lasting gene modification. In human cells, high-fidelity SpCas9 and hyper-accurate Cas9 have demonstrated effectiveness. Adeno-associated virus (AAV) vectors can be divided into two for larger biochemical loads. Dual AAV vectors have been shown to be successful in treating HemA in pre-clinical investigations. In order to integrate human FVIII into the albumin locus,

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two vectors harbouring Staphylococcus pyogenes Cas 9 and guide RNA with human B-domain deleted FVIII were employed. This resulted in liver production of FVIII for at least 7 months without off-target effects or liver damage (Segurado et al., 2022).

III. NAN□TECHN□L□GY REV□LUTI□NI□ING DRUG DELIVERY

1. **Drug Delivery Systems:** Drug Delivery Systems (DDSs) transport a substance (a drug) from the outside to the body's target area. Drug efficacy is decreased and its therapeutic effect on the condition it is intended to treat is diminished when drug accumulation occurs in non-target areas. The DDSs' ability to deliver medications into certain tissues and cells preferentially allows them to successfully treat ailments. DDSs are developed by taking into account:
   - **High Therapeutic Level:** range of a drugs concentration in blood that is effective and safe.
   - **Increasing the Bioavailability of the Drug:** Bioavailability is the percentage of drug that reaches the systemic circulation (or cardiovascular system) to allow the drug to travel through blood vessels and other barriers to reach its target site of action.
   - **Reducing the Side Effects:** The DDSs can be divided into two main types: conventional DDSs and novel DDSs or controlled DDSs.

2. **Conventional DDSs:** These are the traditional approaches used to deliver medications to the body. These methods are more frequently utilised when a drug's rapid absorption is the main objective and a speedy release of the drug is necessary. Simple oral, topical, inhalation, or injectable procedures are some of the traditional medication delivery modalities. These techniques have some drawbacks, including the inability to maintain a steady drug concentration over time. Multiple dosages given at regular intervals are one way to solve this issue. However, this appears to be improper as there is a possibility that the patient would overlook taking the prescribed dose at regular intervals.

3. **Novel DDSs:** According to Reza Rezaie et al., (2018) it is also referred to as controlled-release drug delivery, this method combines cutting-edge methods with novel dosage forms to improve medication potency, regulate drug release, increase safety, and specifically target a drug to a target tissue. Controlled release necessitates two qualities in the release kinetics: predictability and reproducibility.

Table 1: Advantages and Disadvantages of Controlled-Release Drug Delivery

Advantages	**Disadvantages**
(1) Increased medication bioavailability and duration of effect. (2) Reduced drug degradation and loss. (3) Reducing medication concentration variations in plasma. (4) Improved utilization	(1) The materials' potential toxicity. (2) Harmful degradation products. (3) High cost (4) Synthesis procedure.

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NDDSs are divided into four categories including (1) rate-preprogrammed, (2) activation-modulated, (3) feedback-regulated, and (4) site-targeting DDSs.

- **Rate-Preprogrammed DDSs:** Modification of the system design that regulates the diffusion rate of drug molecules through the barrier medium around it affects the rate or speed of a drug release.
- **Activation-Modulated DDSs:** Some physical, chemical, or biological processes, as well as external energy, stimulate the drug's release. Therefore, by adjusting the application procedures or the amount of external energy, the kinetics of release can be altered. Modification of the system design that regulates the diffusion rate of drug molecules through the barrier medium around it affects the rate or speed of a drug release.
- **Feedback-Regulated DDSs:** In this type of DDS, sensors that monitor the concentration of specific biochemical substances are built into the DDS devices (feedback mechanisms), and the concentration of these biochemical agents controls how much medicine is released.
- **Site-Targeted DDSs:** delivers a specific amount of a therapeutic agent for an extended period of time to a targeted diseased area of the body.
  - Passive targeting: This mechanism occurs when macromolecules cling to the targeted tissues as a result of the heightened permeability and retention phenomena.
  - Active targeting: This mechanism occurs when particular interactions occur between the nanocarrier and target cell receptors.

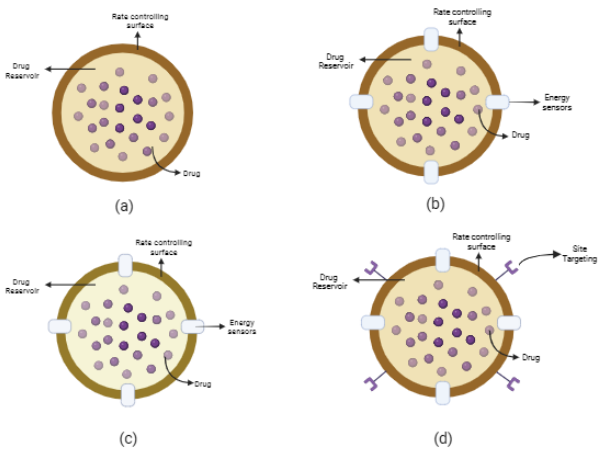

Figure 2: (a) Rate-preprogrammed DDS **(b)** Activation modulated DDS **(c)** Feedback-regulated DDS **(d)** Site-targeting DDS

4. **Routes of Drug Administration:** Route of Administration talks about the path taken by the drug to get into the body.

- **□ral Delivery:** This is the drug administration method that is most frequently utilized. With this approach, both systemic and local effects can be easily attained. Different drug concentrations can be found after each dose because this technique of delivery shows no control over the drug's release. Oral DDSs should consistently deliver a quantifiable and repeatable dose of a medicine to the target site over an extended period of time. Tablets, capsules, syrups, and other products that are taken orally and pass through the digestive system are considered oral delivery.

- **Buccal Delivery:**Buccal mucosa lines the inner cheek, and buccal formulations are injected between the upper gingivae (gums) and cheek (also known as the buccal pouch) to treat both local and systemic illnesses. Buccal delivery techniques include mouthwashes, sprays, gums, bio-adhesive tablets, gels, and patches.

- **Rectal Delivery:**Suppositories are put inside the rectum and liquefy at body temperature in this system. This method of delivery is beneficial for comatose patients and youngsters who are vomiting. It is an efficient method since it avoids the first pass effect.

- **Parenteral Administration:** In this method the drugs are inserted into vascular tissues. This type of administration is preferred in case of emergencies when rapid absorption is required.

- **Topical Administration:** The application of medication to the surface of the skin or mucous membrane of the eye, ear, nose, mouth, vagina, etc. with the intent of limiting the pharmacological effect of the drug to the surface or within the layers of skin or mucous membrane is referred to as the topical route of drug administration. Topical medications are typically available in the form of creams, ointments, gels, lotions, sprays, powders, aerosols, liniments, and drops.

- **Inhalation:** Administration of drug within the respiratory tract by inhaling orally or nasally for local or systemic effect.

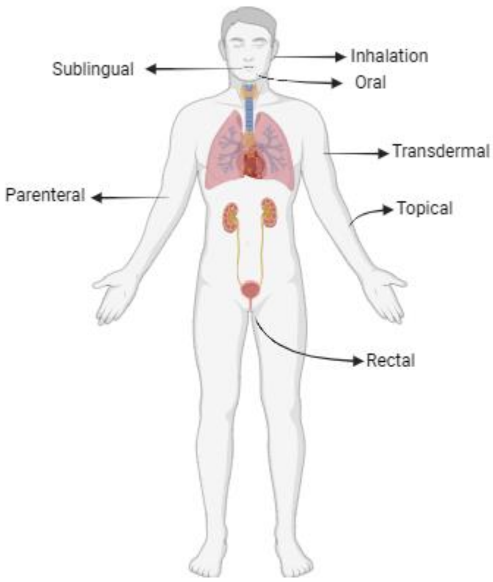

Figure 3: Routes of administration

5. **Drug Delivery Vehicles:** Several methods of packing medications so that they can transport safely throughout the body are represented by drug delivery vehicles. Various

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drug delivery vehicles can help medications get exactly where they need to go, increasing drug targeting. Drug delivery vehicles' (DDVs') size, shape, surface chemistry, stiffness, and chemical composition all have an impact on delivery efficiency. The DDV's core is meant to be a repository for chemotherapeutics, DNA/RNA, or imaging agents. The outer component of DDVs, according to Poon et al. (2020), aids in avoiding innate and adaptive immune detection and is in charge of in vivo navigation.

- **Nanocarriers as Drug Delivery Vehicles:** Nanoparticle DDVs are resistant to the violent conditions of the circulatory environment, extending their halflives; they have high surfacetovolume ratios capable of providing a diverse array of multivalent ligand displays, allowing for enhanced immunestealth, targeting, cellular internalization, and delivery of their therapeutic payload; and they can be prepared from a wide range of inexpensive organic, inorganic, and biological materials used to encase them. Because nanoparticles are materials made at the atomic or molecular level, they are typically small spheres. As a result, they can move more easily in the human body than larger materials. Nanoparticles have distinct structural, chemical, mechanical, magnetic, electrical, and biological properties. Nanomedicines have gained popularity in recent years due to the fact that nanostructures can be used as delivery agents by encapsulating or attaching therapeutic pharmaceuticals and delivering them to target tissues with greater precision and controlled release. Nanostructures remain in the blood circulatory system for an extended period of time, allowing combined medications to be released at the prescribed dose. Because these structures are nanosized, they can enter the tissue system, allowing for easy drug uptake by cells, effective drug transport, and action at the intended spot. The utilization of an optimum nano-drug delivery system is mostly determined by the biophysical and biochemical properties of the targeted medications chosen for therapy. As mentioned by Vinothini & Rajan, (2019) the nanocarriers including nanoparticles, micelles, carbon-based materials, liposomes, niosomes, dendrimers, and other carriers are frequently used for DDSs.

Table 2: Types of Nanocarriers for drug delivery, their properties and representation

Nanocarrier	Definition	Composition/ Structure
Liposomes	Liposomes are small spherical artificial vesicles that contain at least one lipid bilayer.	Composed of phospholipids, especially **phosphatidylcholine, and cholesterol** Can also employ Ligands to detect diseased tissues
Micelle	Micelles are colloidal entities that are amphiphilic. Micelles are made up of molecules with two distinct water affinities.	Composed of ionic surfactants (cationic, anionic)

Polymeric Nanoparticles	Polymeric nanoparticles (NPs) are colloidal systems made from natural or synthetic polymers that can have particle sizes of up to 1000 nm.	**Natural Polymers:** Hyaluronic acid, Chitosan, Cellulose etc. **Synthetic Polymers:** Polyesters, PGA, PLA etc.
Dendrimer	Dendrimer is a synthetic polymer with a repeating chain structure that commonly forms spherical macromolecules.	Has three units: (1) centre of dendrimer or core, (2) repeated units like branches extended from the core, and (3) many functional groups located at the surface of the dendrimer
Niosomes	Niosomes are hydrated vesicular structures containing nonionic surfactants, phospholipids, or cholesterol that transport medicines to specific places.	Composed of: • Non-ionic Surfactants • Phospholipids
Inorganic Nanoparticles	Inorganic nanoparticles are nanoparticles composed of substances other than carbon.	Composed of non-carbon-based molecules, non-metal elements and forms of hydroxides or phosphate compounds.

- **Inorganic Nanoparticles for Drug Delivery:** Several organic nanoparticles derived from polymers, liposomes, and micelles have been researched and successfully created. Some of its intrinsic disadvantages include limited chemical stability, drug release rates that are suboptimal for the specific application, the likelihood of microbiological contamination, and the negative effects of the organic solvents used for particle formation. Because of their high cellular absorption capacity, non-immunogenic reaction, and low toxicity, inorganic nanoparticles have gotten a lot of attention as medication or gene delivery carriers. They have markedly different physical, chemical, and biological properties than their bulk counterparts. Shape and size have been shown to have a considerable influence on the electromagnetic, optical, and catalytic properties of noble-metal nanoparticles such as gold, silver, and platinum.

- **Nonporous Silica Nanoparticles (NSNs):** These are one of the most important types of silica nanoparticles, the silanol groups present on the surface of these nanoparticles can be functionalized easily using amine or carboxyl groups. As a result, NSNs with positive, negative or zwitterionic charges can be prepared. These nanoparticles can be used in hydrophobic drug delivery systems and delivery of gene and small molecules. There are two general strategies for incorporating drugs into/onto silica matrix in nonporous silica nanoparticles: (a) encapsulation and (b) covalence bond. In covalence attachment, drugs are covalently bonded with siloxane groups through degradable ester bonds. However, the encapsulation strategy involves the covalence attachment of drugs with the silica matrix through co-condensation with tetraethyl orthosilicate (TEOS) via the Stöber method (The Stöber process is a chemical process used to prepare silica (SiO_2) particles of controllable and uniform size for applications in materials science). The release of encapsulated drugs can be accomplished by decreasing the pH, since the decrease in pH can lead to decomposition of silica nanoplatform.

- **Mesoporous Silica Nanoparticles (MSNs):** Mesoporous silica nanoparticles are promising candidates as novel drug delivery system. Large internal surface area, extremely high pore capacity controllable morphologies (size and shape), biocompatibility, ease of synthesis, and ease of surface functionalization are among their significant properties in various nanomedicine applications, particularly as nanocarriers for drug delivery systems. In these nanoparticles the encapsulated drugs can be allowed to release by using the GSH-triggered stimulation method. In this strategy disulfide linkages between capping agents and the surface silanol groups of MSNs are reduced by intracellular GSH, this leads to removal of capping agents thereby releasing the loaded drugs.

- **Gold Nanoparticles:** Colloidal gold nanomaterials with different size and shape (e.g., nanorods, nanocages, nano cubes) are good candidates as nanocarriers for biomedicine and drug delivery. The ease of their preparation, their stability, low cytotoxicity, and high extinction coefficient of light from visible to NIR regions have introduced them as important candidates in cancer drug and nanocarrier development. (Mattoussi& Rotello, 2013)

- **□inc □xide Nanoparticles:** In recent years, Zinc Oxide nanoparticles (ZnONPs) emerged as an excellent candidate in the field of optical, electrical, food packaging and particularly in biomedical research. ZnONPs show cancer cell specific toxicity via the pH-dependent (low pH) dissolution into Zn^{2+} ions, which generate reactive oxygen species and induce cytotoxicity in cancer cells. Similar to elemental zinc, ZnONPs are also biocompatible towards normal mammalian cells due to its low dissolution rate, but causes oxidative stress and subsequent cell damage within cancer cells due to its rapid dissolution into Zn^{2+} ions at slightly acidic pH, thereby ZnONPs show pH-responsive cytotoxicity.

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IV. ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING IN DRUG DISC□VERY

The multiple-stage process of developing new drugs uses a lot of resources. It might require up to two decades to get a drug on the market (Grechishnikova, 2021).Through the development of computing and analysis approaches utilising AI and big data algorithms, the limits in the conventional discovery of drugs area brought on by the scale and complexity of biomedical data can be computationally formulated and solved (Lee et al, 2022).Due to their capacity to automatically extract features from the input data and their potential to capture nonlinear input-output correlations, deep learning techniques, which are artificial neural networks that have multiple hidden processing layers, have recently drawn new interest. Algorithms for deep learning have several advantages over more conventional machine learning methods, which rely on hand-crafted molecular descriptors (Jimenez-Luna et al, 2021). Artificial Intelligence can identify hit and lead compounds, as well as accelerate therapeutic target validation and structural design optimization (Paul et al., 2021).

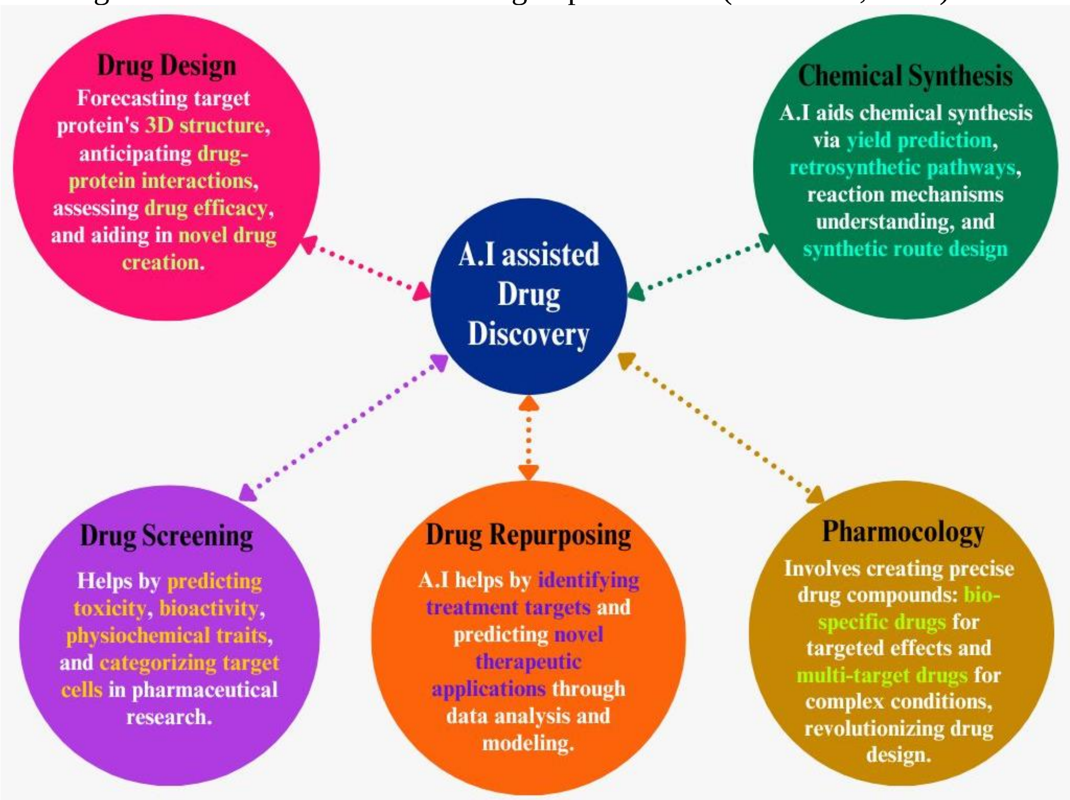

Figure 4: Artificial Intelligence Assisted Drug Discovery (Paul et al., 2021)

1. **Predictive Modelling for Drug Development:** As mentioned earlier, artificial intelligence has abilities to identify hit and lead compounds quickly reducing the overall time needed for drug discovery (Paul et al., 2021; Lee et al., 2022).

   - **Structure Based □SAR/□SPR Modelling:** In the more than 50 years since its start, QSAR/QSPR modelling has advanced significantly. The effectiveness of these computational models in predicting metabolism or biological activity and pharmacokinetic characteristics, such as absorption, distribution, metabolism, elimination, and toxicology (ADMET), is conclusive proof of their influence on drug discovery. The so-called molecular descriptors are often used to translate structural characteristics of molecules (such as pharmacophore distribution, physicochemical properties, and functional groups) into machine-readable numbers for ligand-based QSAR/QSPR modelling. Hand-crafted molecular descriptors cover a wide range and attempt to describe many different facets of the underlying molecular structure. In order to deal with more complicated and possibly nonlinear interactions among the structure of a substance and its physicochemical/biological properties, QSAR/QSPR approaches have generally moved away from the use of simpler models, such as linear regression and k-nearest neighbours, and towards more broadly applicable machine learning techniques, such as support vector machines (SVM) and gradient boosting methods (GBM), often at the expense of interpretability (Jimenez-Luna et al., 2021).

- **Denovo Drug Development:** Due to the cardinality of the chemical domain of drug-like molecules, which is estimated to range in the order of 10^{60}-10^{100}, de novo design, the generation of novel molecular entities with desired pharmacological properties from scratch, can be considered one of the most difficult computerised tasks in drug discovery. De novo molecule production is challenged by combinatorial explosion since there are so many potential atomic kinds and molecular topologies to explore. Ligand-based methodologies can be broken down into two main groups: (i) rule-based approaches, which use a set of construction rules for assembling molecules from a set of 'building blocks' (such as reagents or molecular fragments), and (ii) rule-free approaches, which do not use explicit construction rules. The Topliss strategy for the sequential production of analogues of an active lead chemical to maximise potency is one of the precursors of modern rule-based de novo design. Modern methods for optimisation are based on using a predetermined set of molecular transformations, such as matching molecular pairs or rules-of-thumb for changing functional groups and molecular frameworks. Building block assembly and ligand production are explicitly included in synthesis rules in synthesis-oriented techniques. For example, these methods can be used to create artificially available libraries like BI CLAIM and CHIPMUNK. Since the late 1990s, hybrid approaches have been created to guide the synthesis of novel substances by both maximising their similarity to recognised bioactive ligands and the design's potential for chemical synthesis. Examples of these hybrid approaches are TOPAS, DOGS, and DINGOS. The majority of deep learning-based de novo design studies to date have emphasised ligand-based strategies. Targeting orphan receptors and previously unstudied macromolecules can be accomplished through the promising complementary research area of structure-based generative design (Jimenez-Luna et al., 2021). The majority of recurrent neural network (RNN)-based deep learning models for molecule production use this technology. RNN is frequently utilised to model sequence data. Utilising data from earlier steps is the primary characteristic of RNNs that enables them to function with sequential data. RNN can make connections between far-flung sequence pieces visible. RNNs are unfortunately plagued by the issue of disappearing gradients, which severely restricts their capacity to deal with lengthy sequences. This problem is somewhat resolved by gated recurrent and long short-term memory units. Recurrent neural networks based on short-term and long-term memory have recently been employed in various works for the development of de novo molecules. Simplified

Molecular-Input Line-Entry (SMILES) string input is used by them. The models are forced to produce targeted molecule libraries with the appropriate activity towards the same target when fine-tuning on a smaller dataset with compounds that are known to be active against biological targets. In the reinforcement learning paradigm, the agent (generator in the de novo drug generation issue) performs a step to maximise reward (function computed after SMILES string completion). This step involves choosing the next character during new SMILES string generation (Grechishnikova, 2021).

V. SMART DRUG DELIVERY SYSTEMS AND I□T INTEGRATI□N

Systemic side effects are frequently associated with conventional drug delivery systems (DDSs), which can be attributed to their unpredictable drug release properties and non-specific bio-distribution. Advanced controlled DDSs have been created to achieve the release of payloads at the target places in a spatially controlled manner, overcoming these constraints. Smart-controlled DDSs have an advantage over traditional DDSs in that they can reduce dosing frequency while preserving the concentration of drugs in the targeted organs and tissues for a longer duration. In this way, the controlled DDSs offer insightful information and intriguing characteristics for lowering drug concentration fluctuations, lowering medication toxicities, and enhancing therapeutic efficacy. These drug delivery systems can be developed which can be responsive to various stimuli like pH, Enzyme, Temperature, Redox, Light, Magnetic, ultra sound, and various other stimuli (Liu et.al., 2016). The "internet of things," or IoT, is a network of physical technologies that communicate data using built-in sensors, software, and connection. It enables automated communication and task completion between devices. By increasing productivity, automating operations, and offering cutting-edge data analysis, IoT can change entire sectors. Through smart devices, remote control, and in-the-moment data analysis, IoT-based medicine delivery systems maximise effectiveness, accuracy, and safety (Raikar et.al., 2023). Smart drug delivery systems have a great deal of potential to increase medication adherence and ease the strain of complicated regimens. By utilising their connectivity and smooth data exchange capabilities, IoT-based systems provide special benefits for smart medicine administration (Liu et al., 2016; Raikar et.al., 2023).

1. **Implantable Devices for Controlled Drug Release:** The drug rate of release is influenced by the physicochemical characteristics of the drug, such as solubility, particle size, and molecular weight, as well as the features of the polymeric coating, such as polymer configuration, molecular weight, and coating thickness (Pons-Faudoa et al., 2019). Devices or materials for regulating a chemical's release time, rate, or both are referred to as "controlled release" (Langer, 1990). A range of controlled drug delivery systems have been created during the past few years as a result of the expanding capabilities of conventional drug administration. Amongst these, MEMS-based drug delivery devices, micropumps and osmotic pumps, are used. These devices were created using various manufacturing processes and are used in a variety of administration methods (Sutradhar & Sumi, 2016).

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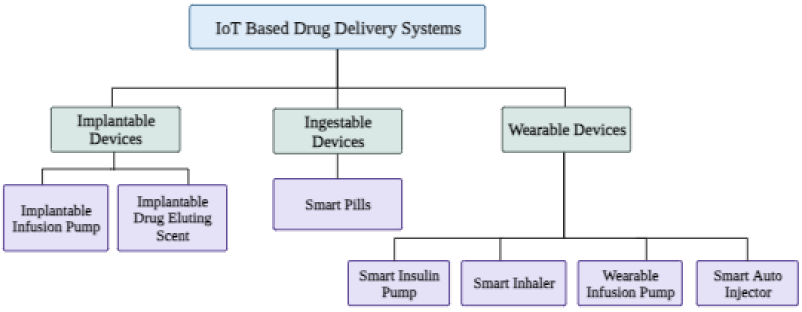

Figure 5: Classification of IoT-Based Drug delivery devices (Sutradhar & Sumi, 2016)

2. **Reservoir-Based Polymer Systems:** Passive implants known as reservoir-based polymer systems is one of the most popular controlled medication delivery methods to date. In these types of systems, a drug core is enclosed by a polymer film, and the polymer's properties (such as its composition and molecular weight), the coating's thickness, and the physicochemical characteristics of the drug, such as solubility, drug particle size, and molecular weight, all influence how quickly the drug is released (Pons-Faudoa et al., 2019; Yang & Pierstorff, 2012). Reservoir-based systems are best suited for either of the following two uses:
   - A localised medication that is administered over a medium to long period of time to a particular area (e.g., an organ, body cavity, etc).
   - A medication depot used in systemic long-term delivery.
   - Reservoir-based polymer systems are categorized into injectable, implants and hydrogels.

3. **Pumps:**

   - **smotic Pumps:** In order to give drugs to animals, Rose and Nelson created osmotic pumps in the 1950s. Since then, a variety of designs have been used in clinical settings to treat human ailments. Drug delivery systems called implantable osmotic pumps were created for long-term, sustained administration of treatments spanning months or years. After the pump is implanted, the mechanism for osmotic pump-driven medication release takes place. A high concentration of osmolytes (salts), or the osmotic engine, propels an osmotic flow of interstitial fluid over the semipermeable membrane. A force is applied to the piston by the inward H_2O flow, which raises the hydrostatic pressure in the osmotic reservoir. When a piston is pushed in the direction of a drug reservoir, the drug solution is injected in an amount equal to the volume that was previously displaced (Pons-Faudoa et al., 2019).

   - **Infusion Pumps:** Pharmaceutical preparations can be administered through a catheter inserted under the skin by wearable infusion pumps. They provide continuous medication throughout the day and are inconspicuous, portable devices that are set up to provide exact doses at predetermined intervals. By preventing disruption to the infusion site, wearable infusion pumps minimise the risk of infection while providing easy and mobile drug delivery. For individualised care, wearable infusion pumps provide exact dosing and can modify medication based on current glucose levels (Raikar et al, 2023).

- **Peristaltic Pumps:** Peristaltic pumps are made up of rotary solenoid-driven systems that are powered by an external source, usually a battery. Peristaltic systems, like infusion pump systems, are loaded through a silicone rubber septum and can be used for years depending on how long the battery-powered device lasts. The advantage of this type of technology is that an external remote control system may regulate how quickly medications are supplied. However, due to their expensive cost, these devices have not yet been widely deployed (Kumar & Pillai, 2018).

4. **Microfabricated Systems:** Electromechanical technologies provide unique approaches to medication release in relation to precise dosing. Microelectromechanical systems (Eg: Microchips) and nanoelectromechanical systems (Nanochannel membranes) are terms used to refer to microscopic and nanoscopic devices containing features in the microscale and nanoscale array, respectively.When these implants are reduced in size, the forces that influence drug release vary in relation to the reduction in area and volume; adhesion and surface tension, for example, have a more significant impact on molecules, which is useful for controlled drug delivery (Pons-Faudoa et al., 2019).

5. **IoT-Enabled Monitoring of Patient Response:** IoT sensors continuously monitor drug delivery parameters, patient responses, and ambient conditions with real-time monitoring and data analytics, enabling quick intervention and improved treatment procedures (Liu et al., 2016). Health care providers may remotely track patient progress owing to remote access and connectivity, which makes them especially useful for telemedicine and the management of chronic diseases. Mobile apps, wearables, and interactive interfaces that encourage increased patient engagement enable patients to actively participate in their therapy, which improves self-management as well as treatment results (Saunders et al., 2019).

   IoT-based drug delivery systems are gaining popularity in healthcare due to their potential to enhance medicine distribution precision, effectiveness, and efficiency. These systems utilize various algorithms for smart medication delivery, enabling data analysis, informed decisions, and treatment optimization. Closed-loop control algorithms, such as in closed-loop insulin delivery for diabetes, monitor real-time sensor data to determine proper dosage or delivery rates. Pharmacokinetic and pharmacodynamic algorithms leverage mathematical models to optimize dosing and predict medication responses based on factors like absorption, distribution, metabolism, and excretion. Machine learning algorithms analyze large datasets to identify patterns guiding dose decisions and improving treatment outcomes. These algorithms enable real-time notifications, adaptive dose adjustments, and dosing suggestions, enhancing drug delivery system efficiency, security, and treatment effectiveness (Hassanzadeh et al., 2019; Raikar et al., 2023).

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VI. CHALLENGES AND FUTURE SC□PE

Drug carrier systems play a crucial role in controlled or targeted drug delivery. Associating established therapeutic compounds with nano-carriers holds the potential to revolutionize drug efficacy assessment and enhance our capacity to address various human ailments. The utilization of nanocarriers as conduits for drug delivery presents a blend of challenges and promising future prospects within the medical realm. Obstacles encompass concerns about biocompatibility and safety, the demand for large-scale manufacturing, maintaining stability and shelf life, achieving precise targeting, surmounting biological barriers, and ensuring efficient clearance and biodistribution. The assurance of biocompatibility and safety remains of paramount importance, while efficient and economically viable methods for mass production are required. The accuracy of targeting is a pivotal determinant for the success of therapeutic interventions, necessitating the circumvention of physiological barriers such as the intricate blood-brain barrier. In the sphere of potential, significant advancements await, including the realm of precision medicine, tailored therapeutic approaches, synergistic combination therapies, the delivery of genetic material like genes and RNA, innovative imaging and diagnostic capabilities, modulation of the immune system, mitigation of unwanted side effects, and the advancement of regenerative medicine. Nanocarriers offer the unique ability to carry diverse therapeutic agents, enabling the pursuit of multifaceted treatments addressing multiple facets of a condition simultaneously. Additionally, their aptitude to serve as imaging agents for diagnostic purposes, interact with the immune system to bolster responses, and reduce systemic side effects associated with conventional drug administration, underlines their vast potential for reshaping medical practices.

Monoclonal antibodies (mAbs), and mRNA gene-based therapy have revolutionized medicine by providing tailored treatments for various illnesses. However, challenges like cost, accessibility, immunogenicity, and delivery techniques remain. Advances in genomics and proteomics will enable personalized medicine, combination therapies, and cancer immunotherapy. Despite these challenges, the future of these medicines is promising, with extended therapeutic applications, vaccine innovation, genetic disease cures, combination therapies, neurological illnesses, and reduced global health disparities. Addressing these issues is crucial for their full potential and proper incorporation into clinical practice.

With breakthroughs in QSAR modeling, de novo molecular design, and synthesis planning, AI applications are gaining traction in drug discovery and design. However, the efficacy of these strategies in generating and synthesizing superior medication candidates has yet to be proven. Deep learning systems, such as graph neural networks and SMILES-based recurrent neural networks, can be used to a broader set of chemical entities and modeling tasks, allowing for more efficient data usage via multitasking and online learning. Although conformation-aware deep learning is still in its infancy, considerable improvement in drug discovery and related fields such as quantum mechanics and material science is expected. In de novo drug design, rule-based and rule-free approaches have been supplemented, with hybrid methods providing a pragmatic answer. Gene expression, conformation space, and ligand binding site information, among other sources of information, will continue to drive innovation in automated synthesis planning and reaction prediction. To develop and test these strategies, more interdisciplinary research is required.

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Significant progress has been achieved in the evolution of implantable microchip technology, starting from its initial inception to the present day. It is evident that in the near future, implantable microchips hold the potential to supplant conventional drug delivery systems that are currently prevalent. As a promising avenue, substantial advancements are required to enhance the capabilities of these implantable microchip devices. These improvements encompass various aspects such as biocompatibility, precise dimensions and contours, heightened patient adherence for administration, and enhanced efficiency in delivering drugs within the surrounding bodily fluids. However, the journey towards realizing these advanced implantable microchips is not without its challenges. The forthcoming development of these microchips faces the task of scaling up manufacturing processes while maintaining quality and efficiency. Furthermore, there lies a necessity to refine the existing implantable microchips, transforming them into multifunctional devices capable of fulfilling diverse biological and therapeutic requirements during their operational period.

The rapid proliferation of IoT medical devices presents challenges due to their battery reliance, necessitating effective power management for device longevity. Merging big data with IoT healthcare systems can provide valuable insights by organizing patient data into comprehensive datasets. IoT-enabled health monitoring systems have revolutionized healthcare by providing real-time disease monitoring, accurate error detection, fewer doctor visits, and reduced patient expenses. However, future research should address potential challenges such as data security, privacy concerns, and compatibility issues. The collection of private health data by healthcare sensors and devices introduces risks of unauthorized access, breaching patient confidentiality. Data security issues include physical protection, secure communication routing, transparent data handling, and resource-efficient practices. Compatibility issues arise from the varied data collection needs of different devices. Addressing societal impacts, ethical considerations, service quality, and refining technological attributes is also crucial for its effective evaluation and implementation.

VII. C□NCLUSI□N

This chapter provides a comprehensive exploration of futuristic endeavors in the realm of pharmaceuticals and DDSs. It delves into the evolutionary journey of pharmaceutical technology, highlighting the imperative for advanced drug delivery methodologies. The realm of biopharmaceuticals, exemplified by groundbreaking innovations such as monoclonal antibodies and mRNA vaccines, offering insights into their potential for treating a range of ailments. Noteworthy breakthroughs like antiamyloidmAbs, now approved for Alzheimer's treatment, demonstrate the industry's commitment to addressing intricate disease processes. The aftermath of the COVID-19 pandemic on the advancements in pharmaceutics is evident in the surge of genetic therapies like CAR-T cell therapy, as well as the development of inhalable mRNA vaccines, demonstrating the field's resilience in times of crisis. Nanotechnology emerges as a pivotal player, revolutionizing drug delivery through nanocarriers that overcome conventional challenges, paving the way for more personalized and efficacious treatments. Incorporation of AI and machine learning into the discovery process of drugs underscores their transformative capabilities in handling complex biomedical data and accelerating hit/lead identification. In the sphere of DDSs, the advent of smart technologies takes center stage, offering advanced mechanisms for precise drug release and real-time monitoring. From implantable devices to IoT-integrated solutions, these innovations not only enhance treatment efficacy but also streamline patient care. Challenges and opportunities abound, from refining nanocarrier drug systems to ensuring data security in IoT devices. The landscape of pharmaceuticals is further enriched by the revolutionary potentials of monoclonal antibodies and mRNA therapies, fostering the dawn of personalized medicine. As we conclude this chapter, we are presented with a dynamic tableau of the pharmaceutical landscape, characterized by unprecedented advancements and promising prospects. This exploration serves as a testament to the pharmaceutical field's unwavering commitment to innovation and its profound impact on healthcare as we navigate the horizon of future trends.

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CHAPTER

Gene prediction through metagenomics

4

Sanjeeb Kumar Mandal, Jyothika Meenakshi Kambhampati, V. Shreya Sharma, Valluru Sai Leela Sirisha, Pokala Sharvani, C. Nagendranatha Reddy, Rajasri Yadavalli and Bishwambhar Mishra

Department of Biotechnology, Chaitanya Bharathi Institute of Technology, Hyderabad, Telangana, India

4.1 Introduction

Metagenomics, which can also be called community genomics, environmental genomics, or microbial population genomics, is a study about whole communities of intricately interconnected organisms in various ecological environments using information from their genome (Dupré and O'Malley, 2007). The term "metagenome" has been initially coined and used by Jo Handelsman in 1998 to speak of the entire microbiota's collective DNA in a specific ecosystem (Handelsman, 2004). Metagenomics can similarly be defined as the use of sequence DNA analysis isolated directly from a sample of the environment or a set of related samples, resulting in at least 50 Mbp of random samples of data in the form of sequence (Kunin et al., 2008). Metagenomics can also be considered a relatively new sector that identifies the overall amount of genetic material present in the collection of genetic components as well as in an organism, including ribonucleic and deoxyribonucleic acid, that are essential for the upkeep of cellular processes (Kumar Awasthi et al., 2020).

Finding the precise species of origin for metagenomic sequences is the goal of taxonomic classification, which is also done largely in an effort to catalog and classify various microbial groups that exist in a certain habitat. As a result, taxonomic classification is an essential step in many metagenomic applications, including disease diagnostics, microbiome analysis, and outbreak tracing, among others. The majority of the constructed sequence composition features are used in current taxonomy classification algorithms, such as oligonucleotide frequency to classify organisms (Kumar Awasthi et al., 2020).

The majority of gene prediction tools created in the 1990s are founded upon single concept to describe the portions coding for proteins and unable to identify genes from the genome with unusual sequence structure. The major problem in the technique of finding genes by gene prediction is the sequence segments of DNA that have a biological function. It may also apply to other functional elements like ncRNA genes, although it notably relates to protein-coding areas. The

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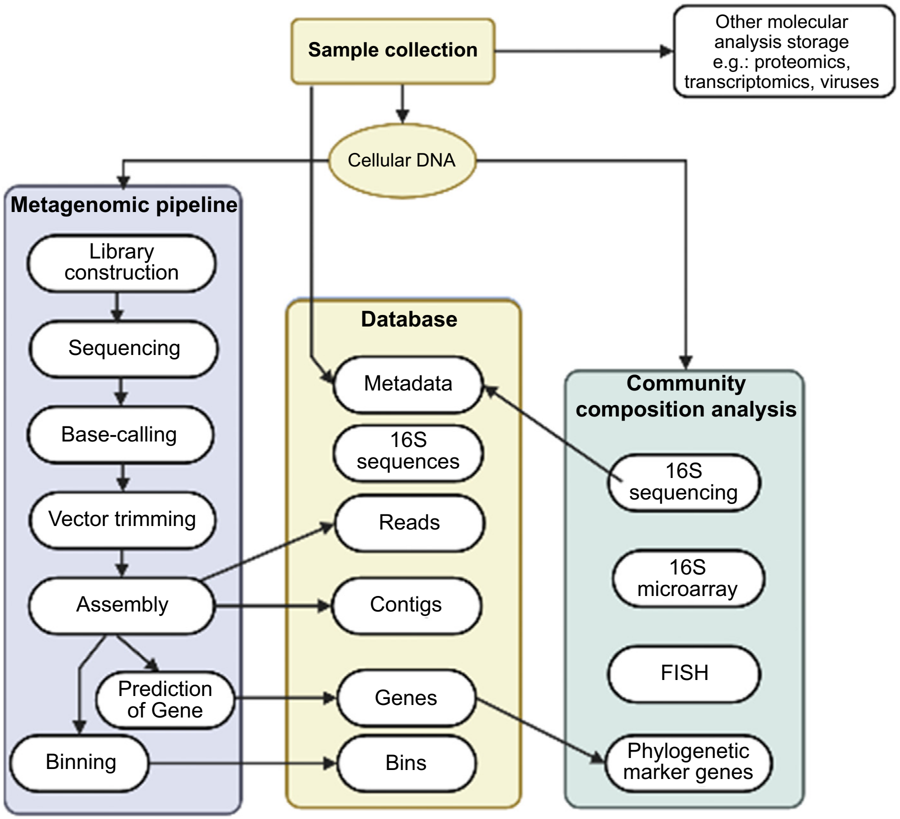

FIGURE 4.1

A typical Sanger-based metagenomic project workflow.

primary goal of the gene prediction problem is to precisely identify every DNA sequence entity's association with region encoding a protein, RNA, noncoding region, or an intergenic region. The sections of DNA between genes are known as intergenic regions (Goel et al., 2013) (Fig. 4.1).

There are three main metagenomic classifications or themes, they are as follows:

1. marker metagenomics, which uses the highly conserved 16S rRNA gene to survey microbial community structure,
2. functional metagenomics, which uses the total environmental DNA to infer the microbial community's potential of metabolism, and
3. novel enzyme detection (Zhao & Bajic, 2015).

4.2 Genomics versus metagenomics

By sequencing the base pairs of an organism's DNA, genomics may ascertain the entire genetic makeup of the organism. The most noteworthy example is the HGP (Human Genome Project), which required 3 billion bp in length sequencing. Nonetheless, an enormous amount of organism's genomes from each of the life three domains—archaea and Eukarya as well as quasi-life forms like viruses—have now been sequenced. Contrarily, in metagenomics, a sample of the genome sequences from a group of organisms with similar habitats is collected. In a broader sense, metagenomics has been defined as any type of analysis of DNA obtained directly from the environment, such as, for instance, screening such DNA for specific enzyme activity in accordance with the right protocols (Hugenholtz and Gene, 2008) (Fig. 4.2 and Table 4.1).

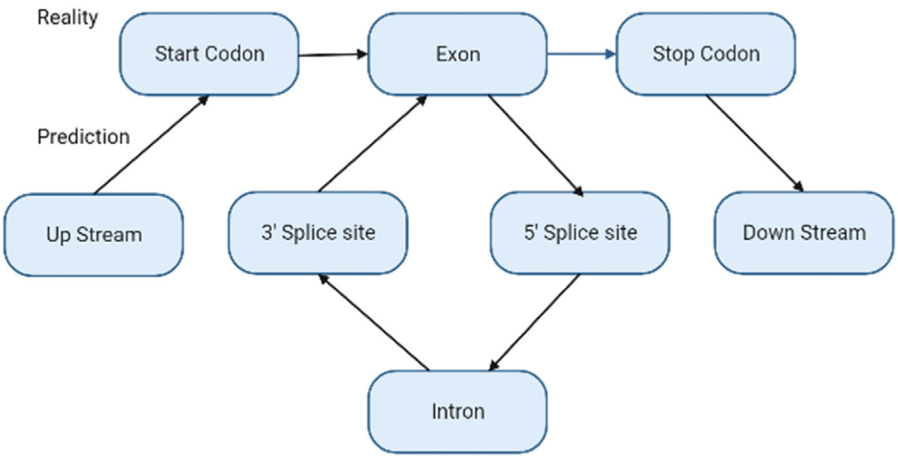

FIGURE 4.2

Transition of states in hidden Markov modeling of eukaryotic gene.

Table 4.1 Comparison between the conventional and metagenomic methods of gene prediction.

Conventional gene prediction method	Gene prediction through metagenomics	References
A sequence similarity search is based on comparing genetic sequences within proteins, ESTs, or other genomes that seem to be similar to the query genome	Exon and signal sequence information are both used to predict genes. Short sequence features, such as polypyrimidine tracts and splice sites, are described as signal sensors. Exon detection must rely on a species-specific pattern of codon use	Salamov and Solovyevand (2011), Liu et al. (2013), Al-Ajlan and El Allali (2018)
When an EST, DNA, or protein and a certain genomic area are comparable, it is possible to infer information about the structure of the gene or region's function	Many gene modeling algorithms have been created, including linear discriminant analysis, dynamic programming, linguistic techniques, neural networks, and hidden Markov models	
Nevertheless, this approach only allows for the prediction of genes with known homologs, leaving out the unique genes that are essential for the metagenomic study	By using this method, unique genes can be easily identified as it is based on signal and exon sequence information instead of homologs	
Large samples will reduce the accuracy of the prediction	Even large samples can be easily predicted without loss in accuracy	
Takes less time to predict a gene	Takes a long time to predict a gene	
Cannot predict the gene relation with other genes	Can predict the gene relation between the different genes in a long sequence	
Common programs used are BLAST, CRITICA, and Orpheus programs	Common programs used are GlimmerM, GeneID, and HMMGene	

ESTs, *Expressed sequence tags.*

4.3 Gene prediction in Eukaryotes versus prokaryotes

Since bacterial genomes typically have a greater gene density and lack intervening sequences in their protein-coding areas, discovery of gene in these genomes is much less challenging (Wang et al., 2004). The longest open reading frames

(ORFs), those run through initial start codon in messenger RNA usually to the following stop codon within the same reading frame, offer a good, although not always precise, forecast of the protein-coding areas. To identify the compositional variations between coding areas, “shadow” coding regions (encoding in the opposing nucleic acid strand), as well as noncoding DNA, a number of techniques have been developed. These strategies make use of several Markov model types. These techniques, which include ECOPARSE, the popular GENMARK, and the Glimmer programme, seem to work well in identifying the majority of protein-coding genes (Wang et al., 2004; Burge & Karlin, 1998).

It is a very different issue in eukaryotic creatures than it is in prokaryotes. After the expression of regions that code for proteins is started at particular sequences of promoter, a splicing mechanism eliminates noncoding sequences (introns) from pre-mRNA, omitting the exons that code for proteins. Mature mRNA can then be translated between the start and the stop codon, frequently in a 50−30 direction, after the introns are removed and other changes are made to the mature RNA. Since intron sequences are present in the eukaryotic genomic DNA, introns that often result in stop codons have the potential to sever the ORF relating to an expressed gene (Wang et al., 2004; Fickett, 1982).

4.4 Significance of metagenomics

The best thing about metagenomics technology is that it provides environmental microbiologists more freedom to quickly discover the huge genetic variety observed in communities of microbes. The analysis of microbial communities can benefit with use of metagenomic techniques. By enhancing the genome with metagenomic analysis, active bacteria in contaminated regions can be evaluated. To identify bacteria and their gene expression, metagenomics is also applied, and metatranscriptomes of the recovered sample can also be analyzed (Kumar Awasthi et al., 2020).

Our knowledge about ecology of microbes as well as its importance in global geochemistry was enhanced because of functional metagenomics. Proteorhodopsin is discovered to be broadly dispersed in aquatic settings, which illustrates how microorganisms may survive in oligotrophic environments and represents one of the most significant discoveries from this research. A great range of microorganisms that had previously escaped conventional microbiology techniques has now been accessible to us due to the field of metagenomics. Metagenomics has contributed to establishing the connection between both pool of genes accessible to a population microbe and the environmental conditions that surround them, going beyond just counting new species. An entirely new reservoir of potential innovative biocatalysts for the biotechnological industry has been made available by the surge in metagenomics data, particularly those from harsh settings (Zhao & Bajic, 2015).

Metagenome searches will always reveal previously unidentified genes and proteins since the vast majority of noncultured microorganisms make up the majority of microbial habitats. This method is therefore preferable to searches in already cultured microorganisms because of the likelihood of discovering unique sequences. Ever since its inception, metagenomics has discovered a considerable quantity of novel encoding genes for compounds or enzymes with a promising prospect for usage in pharmaceuticals or manufacturing procedures (Striet & Schmitz).

4.5 Methods of gene prediction

Shotgun sequencing is used to analyze DNA that has been directly extracted from an environmental sample or a collection of samples that are related. It is a descendant of conventional microbial genomics as well, with the key distinction being that it does not require pristine cultures for sequencing. Its primary objective is to understand how various genes (genomes) interact within a specific community. In genomics, the topic of gene prediction is well-known, and in metagenomics, it still poses a fascinating computational problem (Goés et al., 2014) (Fig. 4.3).

The two primary methods for gene prediction are as follows:

1. Using homology searches to find genes similar to those previously seen (in reference to microbial genomes), evidence-based gene naming methods find genes to forecast genes.
2. Ab initio gene-calling allows for the detection of homologs in the current databases by using the intrinsic properties of the DNA sequence to discriminate between coding and noncoding portions (Kunin et al., 2008).

A crucial first step in the majority of metagenomics analysis methods is gene prediction. Gene prediction is a technique used to locate genes in genomic sequences. Research first successfully found genes in live cells and animals. Yet the process is typically costly and time-consuming. Computational techniques continue to be the most common way to uncover genes, despite the fact that they have shown success in locating genes in both genomic and metagenomes at a fraction of the cost and time of conventional approaches. The two types are

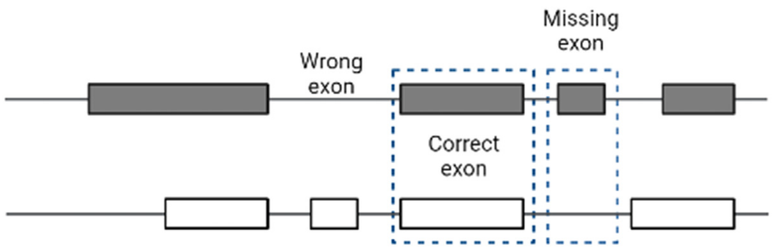

FIGURE 4.3

Assessment of exon-level gene prediction precision.

family resemblance and content-based computational techniques. Methods for identifying genes based on similarity look for similar existing sequences. The basic local alignment search tool is used to compare a putative gene to known genes (BLAST). Nevertheless, this method is expensive and unable to find new species or genes. In an effort to get beyond these restrictions, content-based approaches utilize statistical techniques to find differences between coding and noncoding areas. Despite the fact that these techniques have proven extremely effective with genomic sequences, the nature of the data implies that metagenomics still needs improvement. The short read length and the fractured and fragmented structure of the data provide the biggest difficulties for metagenomic gene forecasting models (Al-Ajlan and El Allali, 2018).

To characterize microbial genomes, a technique called metagenomics isolates genomic sequences straight from the environment without cultivating them first. Despite the fact that computer tools for metagenome analysis are still in their infancy, the volume of metagenomic sequencing data is increasing swiftly. A large percentage of metagenome data currently exists as anonymous, unassembled sequencing reads, unlike the genomic sequences of single species, which can often be assembled and studied using a number of methods. Novel gene discovery is one of the goals of any metagenomic sequencing effort. For example, the majority of the 700 bp-long fragments from short-length Sanger sequencing have unknown phylogenetic origins, necessitating techniques to gene prediction that are distinct from those currently used for single-species genomes. The use of quick, precise techniques with minimal false positive predictions is especially important for the bulk of metagenomic samples (Hoff et al., 2008).

At this point, it is not advisable to attempt a restricted definition of metagenomics, and it is unlikely that it will ever be in either meaning. Metagenomics programs have applications in a number of fields and professions, including ecology, environmental research, human health, and the chemical industry (for instance, metagenomics of the human gut microbiota). Smaller scale techniques, such surveys using 16S rRNA and focused metagenomics, can be used to examine the bacteria in the environment in addition to large-scale shotgun metagenomics. Large-scale shotgun metagenomics and microbial community surveys using 16S rRNA have been conducted for a very long period, but the discovery of the barcoded pyrosequencing technique has advanced these studies (Wooley and Ye, 2009).

Because there is a lot of metagenomic data, metagenomic projects are more complicated than usual (e.g., it is more difficult to simultaneously assemble many genomes than it is to simultaneously assemble a single genome); computational analysis has demonstrated to have an even bigger influence on metagenomic research than conventional genomic initiatives, especially given the unique questions we are raising (e.g., host-parasite—microbe interaction) (Wooley and Ye, 2009).

With the high-throughput sequencing technique employed in metagenomics, which may produce numerous millions of tiny DNA/RNA pieces (or reads) for environmental samples in a single run, we are able to grasp the diversity of microorganisms and how these undiscovered species coexist. It is typically unable to properly assemble these short reads into bigger contigs since the data from metagenomic sequencing originates from hundreds of very different unique species and cannot give a high sequencing coverage of a single species (Zhang et al., 2017).

De novo short read assemblers for metagenomic data such as Meta-IDBA, IDBA-UD, Ray Meta, MetaVelvet-SL, Omega, and metaSPAdes have successfully constructed metagenomic short reads with promising outcomes. If there are numerous species present in the environmental samples, they have difficulty. Analyzing the metagenomics, data involves using these short reads to identify the genes rather than going through the assembly. Gene recognition is essential to completely comprehending the roles, operations, and functions of genes in biological functions (Zhang et al., 2017).

Compared to isolated genomes, it is more challenging to predict genes accurately in metagenomes. One reason might be the fact that most of the fragments (reads) produced by high-throughput sequencing methods are quite short. The majority of genes are imperfect because they have one or two ends that extend beyond the segments, and each fragment sometimes only consists of one or two genes. Another issue is that it's challenging to develop statistical models and choose attributes since the source genomes of the fragments are practically never known or brand-new. Genes may now be identified from DNA fragments obtained via metagenomics using a variety of methods. These prediction methods can be categorized as machine learning, homology-based, or model-based. To evaluate the short sequences, homology-based techniques like CRITICA and the input snippets were often checked by Orpheus against well-known protein databases. These techniques can only be used to find genes that have known isoforms and cannot predict new genes. Model-based techniques, such as MetaGeneAnnotator, MetaGene, MetaGeneMark, FragGeneScan, and to discover genes in metagenomics, Glimmer-MG either employed higher order Markov chain models or hidden Markov chain models. The fundamental drawback of such Markov chain models is the necessity of thousands of parameters for their practical use. Methods based on machine learning, like Orphelia, Metagenomics Gene Caller (MGC), and MetaGUN, frequently created a strong classifier to operate the gene prediction by formulating an effective numerical technique; metagenomic fragments can properly depict their innate association with the target to be anticipated (Zhang et al., 2017).

4.6 Models and algorithms

Without sequestration or culturing, metagenomic sequencing is arising as a potent tool for studying microorganisms from a variety of settings, including the mortal body. One of the most essential problems is correctly recognizing genes from pieces of metagenomic data (Soueiden and Nikolski, 2015). Liu et al. (2013) suggested that in order to probe the magnitude of the microbial world's natural diversity, thousands of prokaryotes have been grown and sequenced. Single genome sequencing, still, is not suitable for the maturity of microbial species, according to disquisition predicated on 16S ribosomal RNA ways, which prognosticate that only a small bit of the living bacteria may be easily insulated and maintained under laboratory conditions. It implies that our current understanding of genomic data is significantly disposed of and does not directly reflect the diversity of microbial species. Also, single genome sequencing fails to reveal the true condition of microbial species in nature because it ignores relations like coevolution and competition between organisms that partake in the same surroundings (Soueiden and Nikolski, 2015).

Metagenomics, a system for analyzing microbial communities by directly gathering and sequencing shotgun DNA fragments from their natural homes without former culturing, can get over these restrictions. The capability to decipher heritable sequences from organisms in their natural homes is growing in strength, particularly for communities that live in or on mortal bodies and are intimately connected to mortal health. DNA sequences can now be produced at significantly advanced increment and far cheaper costs than in the once thanks to the evolutionary growth of sequencing technologies. Numerous samples from various settings, including Minnesota soil, Sargasso Sea, acid mine drainage, and the mortal gut microbiome, have formerly been sequenced using both conventional Sanger sequencing and coming-generation sequencing (NGS) technologies like Roche454 and Illumina (Soueiden and Nikolski, 2015).

Genes can be prognosticate from metagenomic DNA fragments using one of two styles. One is the homology quest-predicated validation-predicated approach. There are comparisons made against well-known protein databases using the BLAST, CRITICA, and Orpheus programmes. Still, it's generally possible to infer functions and metabolic pathways of the projected genes via significant targets with a high position of particularity, if the threshold is strict. By using this system, still, only the genes with previously linked homologs may be prognosticate, leaving out the unique genes, which are vital for metagenomic disquisition. Therefore ab initio algorithms with sufficiently high particularity and substantially advanced perceptivity are essential (Liu et al., 2013).

Several ab initio approaches, which were specifically created for metagenomic fragments in recent times, state that their performance on the 3′ end of genes is original to that of single genomes despite the anonymous and brief partial character of the sequences. The maturity of these earlier ways included modeling sequences in a Markov architecture of different orders. By employing direct polynomial and logistic approximations, MetaGeneMark, for case, uses a sheltered Markov model to show the connections between the frequency of oligonucleotides of various lengths and the Guanine-Cytosine (GC) of a nucleotide sequence. The topmost performance is discovered to be the fifth-order Markov model derived from logistic regression of hexamer frequency. Predicated on the hint frame, which captures the sequence compositions of protein-rendering genes using fitted Markov models with variable-order, hint-MG was created. Orphelia is a recently proposed machine knowledge-predicated metagenomic gene finder that bypasses the Markov model.

Table 4.2 Ab initio gene prediction programs.

Program	Organism	Algorithm[a]	References
GeneID	Vertebrates, plants	DP	Soueidan and Nikolski (2015)
FGENESH	Human, mouse, Drosophila, rice	HMM	
GeneParser	Vertebrates	NN	
Genie	Drosophila, human	GHMM	
GenLang	Vertebrates, Drosophila, dicots	Grammar rule	
MZEF	Human, mouse, Arabidopsis, Fission yeast	Quadratic discriminant analysis	
HMMgene	Vertebrates, *Caenorhabditis elegans*	CHMM	
GRAIL	Human, mouse, Arabidopsis, Drosophila	NN, DP	

[a]DP, *dynamic programming;* NN, *neural network;* HMM, *hidden Markov model;* CHMM, *class HMM;* GHMM, *generalized HMM.*

It incorporates mono- and di-codon use, sequence patterns near translation initiation sites (TISs), ORF length, and GC content to calculate the liability that an ORF canon for a protein (Soueidan and Nikolski, 2015) (Table 4.2).

4.7 MetaGUN for metagenomic fragments based on a machine learning approach of support vector machine

The EDP of codon use, the TIS scores, and the ORF length are three integrated sets of statistics that show the picture capability of a prospective ORF. One of the most vital statistical characteristics for separating protein-rendering regions from noncoding DNA is the triplet nucleotide pattern. In distinction to the maturity of the current metagenomic gene finders, MetaGUN uses an EDP model to characterize the codon operation of ORFs rather than the Markov model. In our earlier disquisition, the EDP model was employed to estimate the coding capacity of ORFs predicated on the amino acid application for single genomes. The codon use for metagenomic fragments is used as an extension of the EDP model to make it more complex. Another vital hallmark that can enhance gene vaccination capability is the pattern of sequences girding TISs. Liu et al. (2013) put into practice a TIS scoring fashion predicated on thousands of previously reckoned TIS parameters that were tutored by the TriTISA computer to determine the TIS scores for a specific ORF. The third integrated particularity, ORF length, has been suggested to be yet another critical criterion for relating genes from arbitrary ORFs in both insulated and metagenomic genomes. Some current metagenomic gene finders with significant accomplishments have recently made specific sweats in predicting proper TISs. A more advanced interpretation of MetaTISA is used in MetaGUN to modify the TISs for anticipated genes. MetaGun creates two gene prophecy modules, the universal and the new modules, to find protein-rendering sequences. Predicated on 261 bacterial genomes that are typical of a wide variety of phylogenetic clades, genomic GC content, and various living conditions, the former is predicated. The ultimate is intended to discover potentially useful DNA sequences with conserved disciplines (Liu et al., 2013).

4.7.1 Architecture of MetaGUN algorithm

MetaGUN uses three way of operation to prognosticate genes. As in former factory MetaTISA, all entering fragments are first assigned to phylogenetic groups using a k-mer predicated naive Bayesian sequence binning approach. It's important to note that pieces in MetaGUN are classified at both the rubric position and the sphere position (Archaea and Bacteria). The former is employed to determine the support vector machine (SVM) classifiers for gene prophecy, and the latter is used to determine the supervised TIS score parameters selection and TIS prophecy also, using SVM classifiers from the supervised universal prophecy module and the sample-specific new prophecy module, all implicit ORFs (full and deficient) are reacquired from the fragments and scored predicated on their point vectors for each sphere singly. In other words, an ORF is given an accretive probability predicated on how far down it's from the separating hyperplane in the SVM classifier's point space. The ORF that has a probability advanced than the specified threshold is allowed to crack for proteins. The TISs of all predicted genes are also moved using a modified interpretation of MetaTISA to produce high-quality TIS reflections (Liu et al., 2013). Yok and Rosen (2011) stated that in bioinformatics, prophecy problems that can be expressed as double groups, analogous as gene identification, protein-protein commerce prophecy, and horizontally transmitted gene discovery, have been successfully answered using the SVM approach. By converting the input patterns into a point space with the help of a proper kernel function, it can develop more precise classifiers for patterns that can't be fluently distinguished in the input space. For a variety of reasons, including point interpretation, running effectiveness, and conception performance, choosing material features for machine knowledge algorithms is vital. There is no exception with the SVM approach. To clarify the picture eventuality, the EDP description of codon operation, the TISs scores, and the ORF length in this work, they employed three sets of statistics (Liu et al., 2013).

4.8 Glimmer

The relating specific of hint is the use of fitted Markov models (IMMs) to record gene composition. IMMs are variable-order Markov chain models that, depending on the volume of training data available, maximize the model order for each distinct oligonucleotide window. The nucleotide distributions are also decided by IMMs between the named order and an advanced order. IMMs make the most complex composition model that the training data sequences support as a result. Hint is a flexible ORF-predicated frame that takes into account how prokaryotic genes can lap as well as upstream characteristics of paraphrase induction spots (TIS), analogous as the ribosomal list point, to divide the sequence into rendering and nonrendering sequence [ribosome binding sites (RBSs)]. Every ORF that is long enough to be pulled by hint is graded grounded on how likely it's for models trained on rendering sequences to induce the ORF compared to models trained on noncoding sequences. The composition via the IMMs, RBS via a position weight matrix (PWM), and start codon use are the features considered in the log-liability rate. Features are treated independently for the sake of simplicity so that the total score can be calculated as the sum of the log-liability rates of each individual point. The set of ORFs with the topmost score is determined by a dynamic programming system with the restriction that genes can't lap for longer than a fated threshold, analogous as 30 bp (Kelley et al., 2012).

4.9 Algorithm structure

The relating specific of hint is the use of fitted Markov models (IMMs) to record gene composition. IMMs are variable-order Markov chain models that, depending

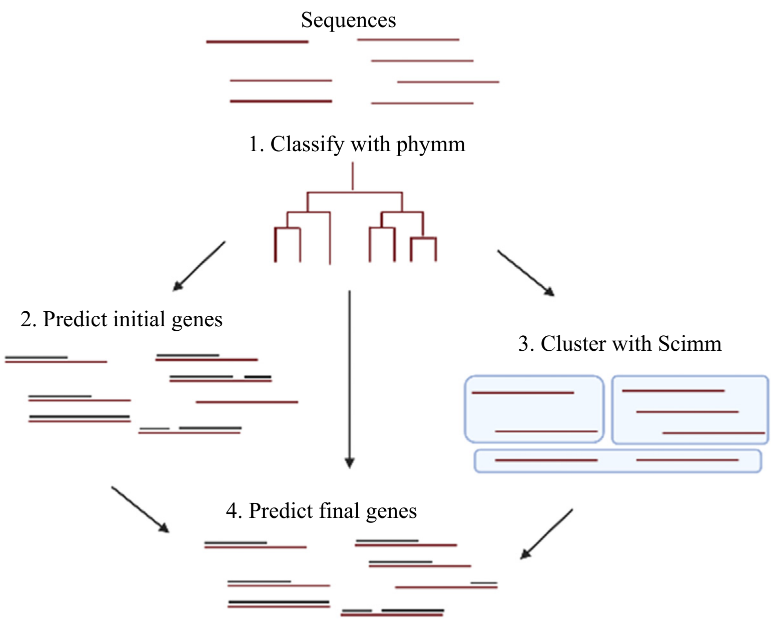

FIGURE 4.4

Glimmer model.

on the volume of training data available, maximize the model order for each distinct oligonucleotide window. The nucleotide distributions are also decided by IMMs between the named order and an advanced order. IMMs make the most complex composition model that the training data sequences support as a result. Hint is a flexible ORF-predicated frame that takes into account how prokaryotic genes can lap as well as upstream characteristics of paraphrase induction spots (TIS), analogous as the ribosomal list point, to divide the sequence into rendering and nonrendering sequence (RBS). Every ORF that is long enough to be pulled by hint is graded grounded on how likely it's for models trained on rendering sequences to induce the ORF compared to models trained on noncoding sequences. The composition via the IMMs, RBS via a PWM, and start codon use are the features considered in the log-liability rate. Features are treated independently for the sake of simplicity so that the total score can be calculated as the sum of the log-liability rates of each individual point. The set of ORFs with the topmost score is determined by a dynamic programming system with the restriction that genes can't lap for longer than a fated threshold, analogous as 30 bp (Kelley et al., 2012) (Fig. 4.4).

4.10 Ab initio gene identification in metagenomic sequences

A probabilistic model of the genomic sequence, which includes both protein-picture and noncoding sections, is used by a traditional ab initio gene discovery approach. The perfection of the estimation of model parameters that are genome-specific has a significant impact on the delicacy of gene vaccination. The three-periodic Markov chain model of a probabilistic model of a protein picture area has 25 parameters, and the number of parameters grows exponentially (by 4 N) with the Markov chain order N. For illustration, in practice, parameter estimation for the fifth-order model is done on a set of vindicated protein-rendering sequences with a total length of 400,000 nt. This is because the advanced the model order, the larger the size of a set of training sequences demanded for parameter estimation without overfitting (Salamov and Solovyevand, 2011).

4.11 Heuristic system of model parameters derivation

Short sequences (lower than 400 nt in length) make up the maturity of metagenomic sequence data, which are mixes of shotgun sequences from multiple microbial community members. The ideal is to determine if a small member has a complete or deficient protein-rendering region. However, we might use a gene discovery algorithm, analogous as GeneMark, if we know or are suitable to prize the genome-specific model parameters hmm, to attack this problem. The absence of the small scrap's genomic terrain, still, prevents the use of conventional styles for parameter estimation. An approach to conclude the parameters of the three-periodic alternate-order Markov model for gene discovery in a detailed (for illustration, 400 nt) sequence member of unknown origin was put forth in a former paper. First, they have discovered connections between a genome's nucleotide makeup and its unique codon frequency. The strongest factors of a genome-wide synonymous codon operation pattern appear to be these dependences. Second, the global nucleotide frequency in the entire genome, which is where the short DNA scrap came from, was estimated from the nucleotide frequency set up in the short DNA scrap. Also, we calculated the genome-specific codon frequency starting with estimated values of the global nucleotide frequency (Zhu et al., 2010).

More specifically, we estimated the frequency of circumstance of each of the 61 codons in a genome-wide set of annotated protein-picture areas in the first step, study of genomes with known reflection, by taking one genome at a time. The codon frequency data establishes 12 positional frequentness that are particular to the genome, f 1X, f 2X, and f 3X, where X is A, C, G, or T in each of the three codon locales. A direct regression on the global nucleotide frequency fX, where fX = A, C, G, and T, was used to predict the f kX values for a sample of known genomes with r = 1, 2, ... R and observed f kX, k = 1, 2, 3 (Zhu et al., 2010).

The direct regression analysis was carried out for 319 bacterial genomes as well as for 38 archaeal genomes now that there are multitudinous farther sequenced genomes accessible. The amount of GC in the genome is significantly linked with the global nucleotide frequency variable. The alternate Chargaff rule asserts that fA fT and fG fC for nucleotide frequency, fX, where X = A, C, G, and T in a single DNA beachfront. As a result, four nucleotide frequency seen in complete genomes may be calculated from only one parameter, the GC content. However, fG fC, also fG = fC = s/2 and fA = fT = (1s)/2 for nucleotide frequency, if s is the genomic GC content. As a result, new graphs representing positional nucleotide frequency as functions of genomic GC attention were created (Zhu et al., 2010).

Also used as a predictor of positional nucleotide frequency of kX, where k = 1, 2, 3 and X = A, C, G, and T, is the s value set up for a brief genomic region. We might get an original approximation of the codon frequency f′ XYZ by assuming that the codon frequency, fXYZ, is commensurate to the product, f 1X f 2Y f 3Z. Fresh correction is handed by the anticipated frequency of the decrypted amino acid, f(s), which is calculated using a direct regression of the observed frequency of the decrypted amino acid in the corresponding proteomes in relation to the genomic GC contents (Zhu et al., 2010).

Ultimately, Zhu et al. (2010) demonstrated that the set of projected codon frequency could be used to estimate all of the parameters of the three-periodic Markov chain model of a protein-rendering area. The multinomial model and the zero-order Markov model were both used to define a nonrendering area model. It was shown that the GC attention of noncoding regions strongly linked with the GC content of the entire genome. As a result, the nucleotide frequencies set up in a fairly small DNA member are accepted as estimates for four noncoding area

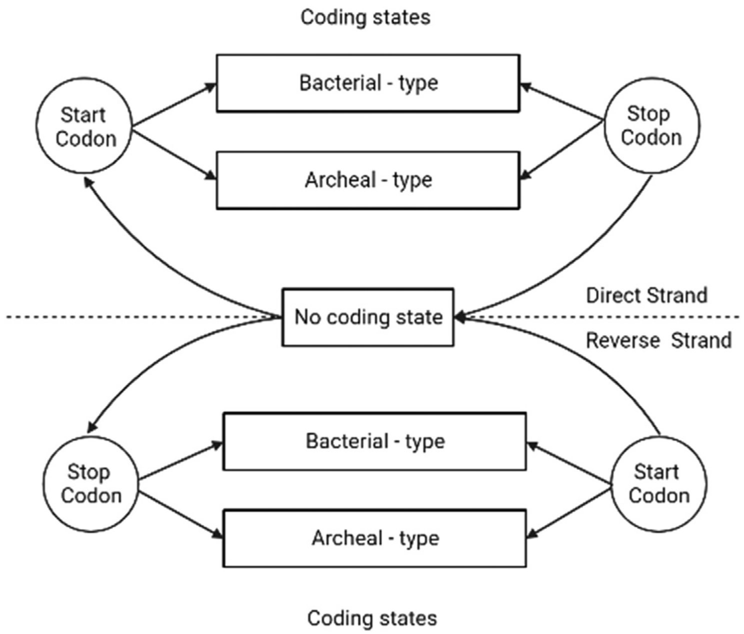

FIGURE 4.5

Heuristic method.

model parameters. In a gene discovery programme like GeneMark, parameterized models of protein- and noncoding areas are thus available (Hoff et al., 2008) (Fig. 4.5 and Table 4.3).

4.12 Orphelia

Short ambient DNA sequences with ambiguous phylogenetic history can be predicted to contain protein-coding genes using the metagenomic ORF finding tool Orphelia. Combining the utilization of mono- and dicodons, sequence patterns at TISs, length of the ORF, and GC content, Orphelia employs ORF fragments to represent mRNAs. This representation is then input into a synthetic neural network to calculate the likelihood that a certain ORF encodes a particular protein. Instead of employing just one model, like Orphelia did, MGC trains a number of models for a variety of predefined GC ranges and then assigns the accurate methodology based on the GC concentration of each segment (Zhang et al., 2017).

This means that MGC employs a two-stage technique to machine learning that predicts genes, first computing six ORF capabilities with the corresponding linear discriminant (i.e., TIS coverage, TIS probability, monoamino acid and diamino

Table 4.3 Comparison between different models for gene prediction through metagenomics.

MetaGUN	Glimmer	Heuristic method	References
Uses an EDP model to characterize the codon usage of ORFs rather than the Markov model	Uses IMMs to record gene composition	Uses three-periodic Markov chain model of a probabilistic model	Zhu et al. (2010), Kelley et al. (2012), Liu et al. (2013)
All entering fragments are first assigned to phylogenetic groups using a k-mer-based naive Bayesian sequence binning approach	Uses a histogram after kernel smoothing with maximum likelihood parameters for the first quartile, and a linear combination of the two for the last quartile	Conventional method for parameter estimation is done	
Using SVM classifiers from the supervised universal prediction module and the sample-specific novel prediction module, all potential ORFs (full and incomplete) are retrieved from the fragments and scored based on their feature vectors for each domain separately	The log-likelihood ratio that a feature was produced by a coding model as opposed to a noncoding model is used to score an ORF and is added to the ORF's total score	ORF score was given using a linear regression of the observed frequencies of the encoded amino acid in the corresponding proteomes in relation to the genomic GC contents	
By converting the input patterns into a feature space with the help of a proper kernel function, it can develop more precise classifiers for patterns that cannot be clearly distinguished in the input space	Every ORF that is long enough to be extracted by Glimmer is graded based on how likely it is for models trained on coding sequences to generate the ORF compared to models trained on noncoding sequences	The nucleotide frequencies found in a relatively small DNA segment are accepted as estimates for four noncoding area model parameters	
Highly accurate as it uses EDP rather than ORFs	Accuracy level is average due to the large size of DNA segments used for gene prediction	Less accurate as compared to other models due to use of some conventional parameters	
The prediction method takes less time	The prediction takes less time	The prediction takes a long time	

EDP, *Guanine-Cytosine;* GC, *Guanine-Cytosine;* IMMs, *Interpolated Markov models;* ORFs, *open reading frames;* SVM, *support vector machine.*

acid scores, monocodon and dicodon scores, and monocodon and dicodon scores), and then predicting the neural network model from the relevant GC range, gene probability of a particular ORF, this uses both the dicodon, which has nine features, and the monocodon scores (Zhang et al., 2017).

4.12.1 Metaprodigal

Prodigal can evaluate sequences in metagenomic mode even if the species is unknown. Prodigal excels in locating in finished genomes, genes, and translation start locations. We chose to build modifications instead of constructing it from scratch; Prodigal's training process might be used to the existing software that would handle metagenomic gene prognostication, such as a translation table, hexamer statistics, motifs at RBS, and the makeup of the upstream base. Due to sampling different training files, this technique has two drawbacks: (1) greater calculation times (50 times longer than the average Prodigal run); and (2) decreased sequence lengths result in higher false-positive rates. MetaProdigal only employs training files that fall within a specific range of GC content relative to the fragments GC in order to handle the first problem. It does this by checking the GC content of each incoming fragment. The second problem was resolved by creating a set of outcomes for each gene in a sequence depending on the length of the input sequence, the number of practice files used to score the sequence, and the length of the gene being scored (Hyatt et al., 2012).

The capability of this approach to computing confidence scores for each gene is a novel feature. Given that the MetaProdigal score is a measure of the chance that a gene is actual as opposed to background (i.e., a gene 1000 * more likely to be real than false would have a score of ln(1000)), the logistic function can be used to convert the score to a percent value between 0 and 100 exclusively.

$$C = e^s/(1 + e^s)$$

where s is the gene's Prodigal score and C is the confidence value.

This approach samples whole genomes from RefSeq at varying fragment sizes to a specific degree of coverage, and it compares the predicted outcomes with the locations of the genes identified in GenBank (either with or without simulated mistakes). Sadly, this strategy has a significant weakness. Since they have not been empirically verified, it is probable that some of the genes RefSeq calls are incorrect. There is evidence that genomes with larger GC contents have more errors. Moreover, when fragment sizes shrink, some anticipated translation initiation locations are likely incorrect, which could have an impact on gene predictions. The chosen genomes do, however, represent a diverse variety of bacteria, Archaea, and GC content levels. Therefore given the aforementioned criterion, researchers chose to examine the MetaProdigal findings on the 50 genomes set from the MetaGeneMark paper (Hyatt et al., 2012).

4.12.2 MGC

MGC is a method for locating both full and missing genes in metagenomic data. In contrast to Orphelia's single system technique, which applies the right model for each fragment depending on its GC content, MGC learns numerous models for a wide range of predetermined GC ranges. To train different models, MGC may divide the training data into segments that are mutually exclusive. Also, the models are separated according to GC content. Due to the advantages that these qualities have shown, MGC employs two of the characteristics of amino acids. In his investigation of codon and amino acid frequency bias in the genome sequence, Merkl found that increasing translational efficiency had an effect on the biassed amino acid composition. When a cell needs a lot of a certain protein, the amino acids that need the least amount of work during translation are more common (El Allali and Rose, 2013).

The state-of-the-art Orphelia tool is comparable to the cutting-edge MGC metagenomic gene caller, which is based on a two-stage machine learning process. Initially, a high-dimensional feature space is reduced into a more manageable one using linear discriminants. The 4096 dicodon frequencies are reduced to one feature, for instance, when the linear discriminant for dicodon usage is used. These properties are not linear throughout the whole GC range, though. Assuming that codon and amino acid consumption are directly influenced by GC content, similar traits should be present in fragments with similar GC concentrations. An enhanced linear combination of the feature space that more precisely defines the coding will result from developing distinct linear discriminants for each GC range. The features of all likely full and incomplete ORFs are extracted from the input segment using the same discriminant function step that was used for training. This is carried out once the models have been trained. The ORF is evaluated based on the segment's GC content using the corresponding neural network model. The output of the neural network is the estimated posterior probability that the ORF is coding. Following the evaluation of all input ORFs by neural networks, the overlap between all candidate ORFs with a probability larger than 0.5 is resolved using the same greedy method as Orphelia (El Allali and Rose, 2013).

The precision and sensitivity measures, which rate how well-annotated genes can be recognized and how well gene predictions are made, are used to assess the efficacy of MGC. According to their GenBank annotations, from chosen random replications of 10 bacterial and 3 archaeal genomes, performance metrics are produced for predicted genes in chunks with a length of 700 base pairs. FNgene is the number of ignored genes, TPgene is the number of ORFs that match at least 60 bp on an annotated gene in the same reading frame, FPgene is the number of predicted ORFs that do not match the annotation, and FNgene is the number of missed genes. The results continued to be compared by using the positive probability score, a sensitivity metric employed by metagenomic gene discovery tools like

MetaGene, FragGeneScan, and Orphelia. This calculation ignores the number of genuine negatives (El Allali and Rose, 2013)

$$Sens = TP_{gene}/TP_{gene} + FN_{gene}$$
$$Spec = TP_{gene}/TP_{gene} + FP_{gene}$$

The harmonic mean is also used to combine the sensitivity and specificity:

$$Harmonic\ Mean = 2 \times Sens \times Spec/Sens + Spec$$

TP_{TIS} stands for the correctly predicted TIS within those forecasts, and TP_{gene^*} refers to a subset of TPgene predictions with an annotated TIS within the segment.

$$TIS\ correctness = TP_{TIS}/TP_{gene^*}$$

Both traditional and metagenomic gene discovery need good TIS forecasting, which is vital and difficult to do. This is important for the metagenomic process' future experimental phases. To choose the appropriate TIS, MGC uses linear discriminant TIS models. The TIS correctness score may be used to gage how accurate this forecast is. An incomplete collection of the anticipated genes with identified TIS is used to calculate the TIS correctness measure. Since they anticipate different amounts of genes, the two approaches cannot be directly compared using this statistic. The TIS accuracy can be improved in a similar way to how sensitivity and specificity measures can (El Allali and Rose, 2013).

4.13 Metageneannotator

Sometimes the target genetic sequences are too short. As an example, second-generation DNA sequencers that employ high throughput sequencing, especially those of microbial genomes, produce a substantial amount of very short sequence reads. The majority of traditional gene-finding methods are useless on such sequences. One of the most recent approaches for determining genes from such brief anonymous sequences is MetaGene (MG). Without any prior training, by assuming relationships between a sequence's GC content and dicodon frequencies, MG accurately determines genes on short anonymous sequences. Genes that use different codons than typical genes are less vulnerable to MG, and there is no model for the RBS, which makes it difficult to successfully employ MG to study a range of bacterial genomic sequences. These restrictions are not important when using MG and working with relatively small sequences that make up one or two truncated genes (Noguchi et al., 2008).

A new version of the MetaGeneAnnotator (MGA) has been released that corrects these issues and enhances the program's usability. Because prophage gene statistical models are included, the MGA can still automatically identify mosaic structures linked to phage infections and/or lateral gene transfers in addition to chromosomal backbone genes. MetaGeneAnnotator is a program for finding genes in phages and prokaryotes. The MGA's adaptable RBS model based on complementary sequences of the 30 tail of 16S ribosomal RNA accurately predicts the start of gene translation even when the input genomic sequences are brief and anonymous. The MGA properties have significantly improved the gene prediction accuracy on different bacterial genomes (Noguchi et al., 2008).

4.14 Predictions on short genomic sequences

The MGA maintained strong accuracy ratings for segments under 1 Mb in each index. For input sequences longer than 40 kb, Glimmer3 sensitivities and specificities are both quite high, but as the input sequence length decreases, the start codon prediction's accuracy quickly degrades. This is due to the fact that the Gibbs sampling approach needs a large number of positive (RBS) sequences in order to identify the proper motif. A 40 kb area contains an average of 40 genes (or RBSs) and has a start codon sensitivity of 57% for Glimmer3. Owing to an issue, GeneMarkS and Glimmer3 most likely also share, it does not take input sequences that are less than 1 Mb. In contrast to these tools' RBS models, the MGA simply evaluates the RBSs of nine hexamers as candidates, and only a small number of sequences are needed to estimate the RBS model's parameters. Consequently, the MGA only requires 500 kb (or 500 genes) to effectively adjust the RBS model to the input pattern, and even in 40 kb sequences, its sensitivity to start codons is sufficient (75%) (Noguchi et al., 2008).

4.15 Predictions on long genomic sequences

All of the prediction algorithms exhibit very identical sensitivity (97%) for whole genomes and 1-MB subsequences but the MGA has much greater specificity (93%) than the others (90% in GeneMarkS and 86%–87% in Glimmer3). In other words, at the same degree of detail, the MGA's sensitivities may be greater than those of the others. Despite the fact that the Gibbs sampling technique was used to train both of these RBS models, the MGA (78%) and GeneMarkS (77%), as well as Glimmer3, demonstrate lower sensitivity to start codons (Noguchi et al., 2008).

Comparing the two datasets, Glimmer3 exceeds GeneMarkS in terms of mean sensitivity to start codons and comprises six whole genomes (one archaea and five bacteria) with moderately large RBS map distributions. The MGA's effectiveness in this dataset is dependable and outperforms the others, especially for *Clostridium acetobutylicum*. The MGA exhibits a considerable increase in sensitivity to both genes and begins codons while maintaining specificity when compared to the original MG. These findings show how well our core RBS model is in differentiating between different RBS types (Noguchi et al., 2008).

4.16 Applications of metagenomics

With the rise of low-cost, high-throughput screening methods, such as Sorcerer II Global Ocean Sampling and the project comparing 42 viromes and 45 different microbiomes, metagenomic sequencing projects have grown exponentially (Rosen et al., 2009). Since the development of efficient metagenomic techniques, which are now being widely used to discover novel enzymes, and the integration of these techniques with cutting-edge sequencing technologies, they will soon supplant current techniques, particularly those that depend on culture. The use of metagenomic techniques has the potential to produce a large amount of data and information (Zhou and Troyanskaya, 2015). Computational tools and bioinformatic techniques are frequently used to organize the numerous sequences obtained from high-throughput metagenomic projects.

4.17 Agriculture

Microbial communities live in the soils where plants grow; 1 g of soil contains roughly around a hundred to thousand microbial cells, which together make up about a Gigabase of sequence data (Vogel et al., 2009). Despite their economic significance, the microbial communities that live in soil are among the most complicated that science has ever encountered (Vogel et al., 2009). In order for plants to grow, microbial communities provide a variety of ecosystem services, including nitrogen fixation, nutrient cycling, disease suppression, and other metal sequestration (Handelsman et al., 2007). Through the study of these microbial communities without regard to culture, functional metagenomics techniques are used to investigate the connections among plants and bacteria (Charles and Marco, 2010; Bringel and Couée, 2015). By utilizing the interactions between microorganisms and plants, metagenomic approaches can aid in better detection of diseases in crops and livestock as well as the ability to adapt improved farming practices resulting in better crop health by understanding the relationship between plants and microbes. Metagenomic methods have made it possible to gain a perspective into the function of initially undiscovered or uncommon communities in nutrient cycling and the encouragement of plant growth (Handelsman et al., 2007).

4.18 Biofuel

Biofuels are fuels made from the conversion of biomass, such as the production of cellulosic ethanol from the cellulose found in switchgrass, maize stalks, and other biomass (Handelsman et al., 2007). This procedure depends on microbial associations that break down the cellulose into sugars, which are then fermented into ethanol. Methane and hydrogen are just two of the bioenergy sources that microbes can produce (Handelsman et al., 2007). Novel enzymes with higher productivity and lower costs are needed for the effective industrial-scale breakdown of biomass (Hess et al., 2011).

The interrogation of complex microbial ecosystems using metagenomic methods enables the focused screening of enzymes having industrial uses in the generation of biofuels, such as glycoside hydrolases (Li et al., 2009). Understanding how these microbial communities function and managing them both require the use of metagenomics. Metagenomic techniques enable comparisons between convergent microbial systems, such as biogas fermenters (Jaenicke et al., 2011) or insect herbivores, such as the fungus garden of the leafcutter ants (Suen et al., 2010).

4.19 Biotechnology

A wide variety of biologically active compounds are produced by microbial communities and are employed for communication and competition (Handelsman et al., 2007). Many of today's medications were discovered in microbes, and latest developments in extracting the genetic wealth of bacteria that cannot be cultured in vitro have led to the discovery of new genes, enzymes, and other natural products (Simon & Daniel, 2011). Metagenomics has been used to generate agrochemicals, medicines, fine chemicals, and commodity chemicals, and the advantages of enzyme-catalyzed chiral synthesis are becoming more widely acknowledged (Wong, 2010). The bioprospecting of metagenomic data employs two forms of analysis: function-driven screening and a sequence-based screening. While the function-driven sequencing is used for an expressed phenotype, sequence-based screening techniques are used for interesting sequences (Schloss and Handelsman, 2003). Following biochemical characterization and sequencing analysis, function-driven analysis searches for clones that exhibit a desirable trait or advantageous behavior. This method is limited by the lack of an appropriate screen and the precondition that the required feature be expressed in the host cell. The reduced rate of discovery (almost less than one per 1000 clones tested) and labor-intensive nature of the process further limit this method (Kakirde et al., 2010). In contrast, sequence-driven analysis creates PCR primers from conserved DNA sequences to test clones for the desired sequence (Schloss and Handelsman, 2003). Using a sequence-only approach reduces the amount of work required even more than cloning-based approaches. Because highly parallel sequencing generates more sequence data, high-throughput bioinformatic analysis pipelines are required (Kakirde et al., 2010). The scope and precision of the genetic variants listed in the sequence databases place restrictions on the sequence-driven approach to screening. Depending on purpose, the magnitude of the sample to be screened, and other criteria, investigations in practice combine both functional and sequence-based techniques (Kakirde et al., 2010; Parachin and Gorwa-Grauslund, 2011). The Malacidin antibiotics provide an excellent illustration of metagenomics' potential as a tool for drug discovery (Hover et al., 2018).

4.20 Ecology

Insights into the functional ecology of environmental ecosystems can be gained from metagenomics (Ji et al., 2011). According to a metagenomic investigation of the microbial groups discovered in Australian sea lions' defecations, fecal matter of sea lions may be a significant source of nutrients for aquatic habitats because they are nutrient-rich. This is due to the bacteria that are skilled at converting the nutrients in the feces into an accessible state which can easily be absorbed into the food chain when they are ejected concurrently with defecations (Lavery et al., 2012). A wider range of applications for DNA sequencing include the identification of species in a body of water, (Richards, 2013) the detection of diet components in blood meals, (Chua et al., 2021) the identification of airborne particles, samples of dirt, and animal feces (Chua et al., 2022). The distribution of invasive and endangered species along with seasonal population trends can be determined.

4.21 Environmental remediation

Metagenomics can enhance methods for assessing how contaminants affect ecosystems and for sanitizing contaminated areas. The likelihood that bioaugmentation or biostimulation trials will be successful and estimates of the ability of polluted locations to recover from pollution will both improve with increased knowledge of how microbial populations respond to contaminants (George et al., 2010).

4.22 Gut microbe characterization

Microbial communities are essential for maintaining human health, yet little is known about their makeup or how they work (Zimmer, 2010). Characterization of the microbial groups from several body locations from more than one individual can be done using metagenomic sequencing. This is a component of the Human Microbiome Initiative, main objectives of which are to ascertain whether the human microbiome has a core, to comprehend the changes in the microbiome that are related to human health, and to create new technological and bioinformatics tools to help achieve these objectives (Nelson & White, 2010). According to research, persons with irritable bowel syndrome have 25% fewer genes and less bacterial diversity than people without the disorder, suggesting that changes in the variety of their gut microbiomes may be related to their symptoms. The fact that only 31%–48.8% of the reads could be aligned to 194 publicly available human gut bacterial genomes and 7.6%–21.2% to bacterial genomes in GenBank suggests that much more research is still required to identify novel bacterial genomes, despite the fact that these studies highlight some potentially useful medical applications (Perez-Muñoz et al., 2017). High-throughput DNA sequencing was used in the Human Microbiome Project (HMP) to assess the microbial communities in the gut. HMP demonstrated that numerous metabolic pathways were prevalent throughout all body habitats with varied frequency, in contrast to individual microbial species. The human microbiome project examined microbial communities of 649 metagenomes collected from seven primary body locations on 102 individuals. The metagenomic analysis of 168 functional modules and 196 metabolic pathways in the microbial ecosystem revealed niche-specific abundance variations.

These included the breakdown of glycosaminoglycans in the gut and the transfer of phosphate and amino acids in the posterior fornix that were related to host phenotype (vaginal pH). The HMP has demonstrated the importance of metagenomics in diagnostics and evidence-based medicine. As a result, metagenomics is an effective technique for tackling many of the crucial problems in the field of personalized medicine (Abubucker et al., 2012). Metagenomics can be used to analyze the gut microbiomes of animals and make it possible to find bacteria that are resistant to antibiotics (Chua and Rasmussen, 2022). Monitoring the transmission of diseases from wild animals to domesticated animals and people may be affected by this. We can also study the genome of ancient microorganisms through a branch of microbiology called paleomicrobiology. Paleo-microbiologists investigate the epidemiology of infectious diseases that were prevalent in antiquity and map the historical patterns of disease migration. They examine the gut microbiota to understand the dietary aspects of our ancestors using petrified feces (known as coprolites) (Warinner et al., 2015). Forensic paleo-microbiologists have examined samples of human origin to learn more about illnesses that have affected humans in the ancient times, such as infections caused by parasitic, viral, and bacterial infections (Rivera-Perez et al., 2018).

4.23 Infectious disease diagnosis

It might be difficult to distinguish infectious diseases from noninfectious diseases and pinpoint the underlying cause of inflammation. For instance, despite intensive testing employing cutting-edge clinical laboratory techniques, over fifty percent of cases of encephalitis go undetected. By comparing the genome obtained from a patient’s sample to the databases of microscopic human pathogens and various other bacterial, viral, fungal, and parasitic organisms, and databases on antimicrobial resistance gene sequences with associated clinical phenotypes, clinical metagenomic sequencing offers promise as a sensitive and quick method in diagnosing infections.

4.24 Arbovirus surveillance

The diversity and ecology of the pathogens carried by hematophagous (blood-feeding) insects like ticks and mosquitoes have been characterized to a great extent by the use of metagenomics (Zakrzewski et al., 2018; Thoendel et al., 2020; Parry et al., 2021). Public health professionals and institutions use metagenomics to monitor arboviruses (Batovska et al., 2017, 2019).

4.25 Forensics

Microorganisms are present in humans as part of their physiological development. The human microbiome is made up of these microflorae as a whole. The normal microflora can be examined to identify a person because the set of these microflora varies between individuals and thus serves as a forensic signature (Thursby and Juge, 2017). Additionally, because there are a variety of native microbes to the various human organs, it may be possible to determine the source of biological evidence, which can be used to access the degree of human interference in a crime (Meadow et al., 2015). The United States of America's (USA) Federal Bureau of Investigation (FBI) has established the Scientific Working Group on Microbiological Genetics and Forensics (SWGMGF), which establishes the framework for microbiological forensics (Budowle et al., 2008). The SWGMGF aims to disseminate information and guidance on the best practices for retrieving information from physical evidence. Details may include the type of microbial toxins used, the offender or victims, and the instruments used during the crime's commission. DNA profiling is an effective method for locating and removing the source of biological evidence. To characterize the microbial evidence more precisely, it can be combined with other powerful techniques like analytical chemistry, pattern matching, and microscopy (Magalhães et al., 2015). Whole genome sequencing (WGS) is used to sequence the isolated microorganisms. Additionally, the metagenomes of various ecosystem niches are sequenced and analyzed. The creation of the microbial genome databases is then made possible by the sequencing data. These databases allow for forensic analysis of the microbe using comparative genomics (Garza and Dutilh, 2015).

4.26 Drug discovery

It is crucial to prioritize the functionality in search of obtaining the pharmaceutically active ingredients. The goal of the research is to find the active metabolite with the preferred functionality that has been pharmaceutically validated. Not only have biosynthetic gene clusters been quickly classified as a result of shotgun metagenomic sequence analysis, but the corresponding biochemical assembly has also been predicted. Although the standalone bioinformatics and HTS approach can only predict a small subset of gene clusters, the better initiatives have enabled the scientists to discover novel active metabolites with potential pharmaceutical value. Nowadays, research is focused on targeted screening, which takes into account the context of the metagenome under study, rather than functionally annotating the gene clusters found in metagenomes.

4.27 Enzymes

Exploration of genes using the integrated metagenomic approach has increased at an exponential rate (Alberts et al., 2002). Diverse metagenomes, including those of insects (lignocellulolytic enzymes), aquatic environments, vertebrate guts, different soils, and extreme environments including acid mine drainage, halo alkaline water bodies, have all been used to isolate novel enzymes (Lee and Lee, 2013). There are two fundamental metagenomic strategies: homology and functional screening, depending on the target. Both strategies call for the creation of a library where the full metagenome is cloned. It is then screened for novel genes with either novel or well-known properties, including its encoded products such as antibiotics (Ab), genes that are resistant to Ab, lipases, oxidoreductases, etc. (Ngara and Zhang, 2018).

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14

Food Colours Toxicology and Food Safety

Vanga Sri Varsha, Tanmayi Boreda, Adithi Reddi Kamana, Sanjana Reddy Pailla, Yashasvi Kambhampati, Gourav T, Ashoutosh Panday, Sanjeeb Kumar Mandal and Bishwambhar Mishra
Department of Biotechnology, Chaitanya Bharathi Institute of Technology, Hyderabad, India,

14.1 Introduction

Food colourings play an important role in making foods attractive, appealing, and appetising. they have great impacts on advertising products as well (Shamina, Shiva, and Parthasarathy 2007). Naturally produced colours from fruits, vegetables, and metals have been used since ancient times. Examples of such food colours are paprika, turmeric, saffron, beetroots, iron, copper, and metal oxides. Wine was coloured artificially since 300 BC (Frick 2003). The earliest recorded use of food colours was 2600 BC in China, and food dyes were reported to have been used by the Europeans in the Bronze Age. Candy was coloured with wine by the Egyptians in 1500 BC to improve the appearance to consumers (Downham and Collins 2000; Frick 2003).

Sir William Henry Perkin contrived the first synthetic dye, known as mauvine or mauve, in 1856. This marked the first synthesis of various dyes from petroleum products such as aniline. In fact, they were referred to as “coal-tar” dyes because their initial product was coal (Frick 2003; Morrell 1993). Figure 14.1 depicts the timeline of historical natural food dye use, including William Henry Perkin’s mauve, the first artificial color.

14.1.1 Early Regulations

In the 1880s, the addition of food colours was being monitored by the federal agencies of the United States. The US Department of Agriculture (USDA) researched food colours in their Department of Chemistry and initially authorised the usage of colour additives in butter and cheese. Many food products were sold with the addition of food colours in the 1900s and caused harm to consumers as they contained

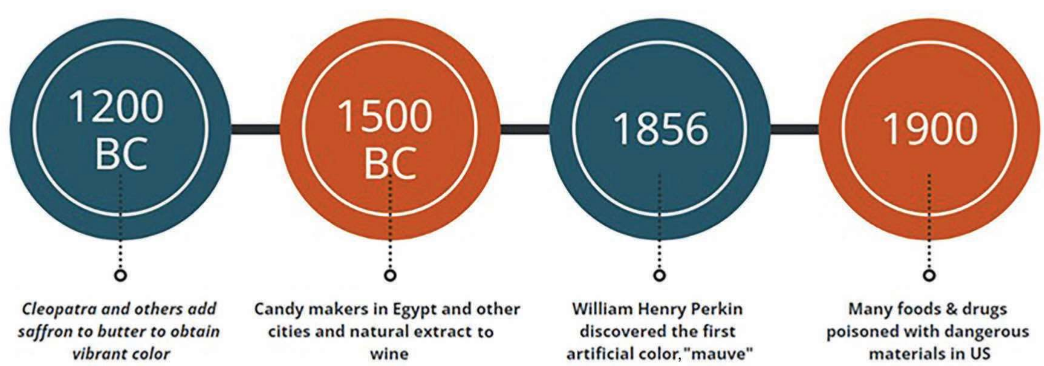

FIGURE 14.1 Timeline of the usage of food colours in history.

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toxicants, irritants, and allergens as well as harmful metals such as lead, mercury, and arsenic (Harp and Barrows 2015). By 1906, Congress outlawed the use of poisonous and toxic food dyes to enhance appearance and to mask any damage to products. Food colours were now classified into three types: mixtures, lakes, and straight colours.

Mixtures: These are colours obtained on mixing two or more food colours or non- coloured diluents without performing any sort of chemical reactions (Bastaki et al. 2017).

Lakes: These are straight colours that are chemically reacted with substrates or precipitates; they must be made from certified and approved straight colours. Lakes generally use aluminium cations as their precipitates and aluminium hydroxide as the substrate. Blue 1 Lake is one such example (Harp and Barrows 2015; Bastaki et al. 2017).

Straight Colours: These are additives that are not reacted or mixed with chemicals or any other substrates. A few examples of such colours are FD&C Blue 1 or Blue No. 1 (Bastaki et al. 2017).

The USDA worked to make a list of seven straight colours which were sanctioned for use in edible products. These approved colours were issued by the Food Inspection Decision (FID). By 1931, 15 approved and certified colours were in use including six of the seven colours approved by the FID: FD&C Blue No. 1 (Brilliant Blue FCF), FD&C Blue No. 2 (Indigotine), FD&C Green No. 3 (Fast Green FCF), FD&C Red No. 3 (Erythrosine), FD&C Yellow No. 5 (Tartrazine), and FD&C Yellow No. 6 (Sunset Yellow) (Karajiannis and Fish 2010).

In 1938, the Food, Drug & Cosmetic Act authorised harmless coal-tar colours. The approval of lakes was included, and the initial use of lakes was to dye eggshells. The FDA held several public hearings to discuss the addition of diluents to additives. The procedures for adding new and permissive colours and certifying colours was also discussed in these hearings (Karajiannis and Fish 2010; Wrolstad and Culver 2012).

Many youngsters were ill in the fall of 1950 after consuming orange-coloured Halloween candy which contained 1–2% FD&C Orange No. 1, a food-safe colorant. A year later, US House Representative James Delaney held hearings on the potential carcinogenicity of pesticide residues and food additives (Bansal et al. 2017). These instances caused the FDA to reconsider all the colour additives listed; in subsequent years, the FDA discovered that multiple caused severe side effects and withdrew them from the market. At the time, coal was no longer the chief raw material source to produce colorants (Wrolstad and Culver 2012; Downham and Collins 2000).

The Color-Additive Amendments of 1960 redefined the term “color additive” and stipulated that only additives recognised as “appropriate and safe” be used in food products. In response to these modifications, the FDA updated the procedural guidelines for the petition process. In accordance with these regulations, the roughly 200 colour additives in use at the time were provisionally listed and permitted to be used for a limited period until they were either officially listed or terminated owing to safety concerns or a lack of economic interest. A colour additive could not be listed permanently for a proposed application unless scientific evidence supported its safety (Burrows 2009).

The 1960 Amendments included the Delaney Clause, which prohibited the inclusion of any colour additive that was known to cause cancer (Weisburger 1996). After 1960, the FDA gradually took colour additives off the provisional list by either listing them permanently or terminating their listing (Barrows, Lipman, and Belai 2014). Only colour additive lakes are provisionally listed now, with efforts to permanently list the remaining roughly half of the 1960 additives (Coultate and Blackburn 2018). In conclusion, the FDA has a long history of regulating colourants at the federal level, and it remains a key priority to ensure that consumers receive safe and correctly labelled products.

14.2 Purpose of Food Colours

Food colour, taste, freshness, and quality play massive roles in appealing to consumers (Garber, Hyatt, and Starr 2000; Drake 1975); in fact, the most significant sensory characteristic in the sector of foods and beverages might be colour. The colours of foods affect people’s gustatory perceptions and gives consumers an idea about the quality and flavour of the foods. Food colours can also be associated with specific brands (Purba et al. 2015) and have impacts on the marketing of food products (Garber, Hyatt, and Starr 2000).

14.3 Permitted Colours

Food colouring additives are used to create an attractive appearance. Some of the allowed engineered food tones include reds (Ponceau 4R, Carmoisine, and Erythrosine), yellows (Tartrazine and Nightfall Yellow FCF), blues (Indigo Carmine and Splendid Blue FCF), and greens (Fast Green FCF) (Khera, Munro, and Radomski 1979).

14.3.1 Types of Food Colours

Food colours are of two sorts, colours and lakes. Colours disintegrate completely in water and are accessible as fluids, granules, or powders. Colours in foods are utilised in refreshments, dairy items, pie fillings, popsicles, jams, pet food sources, and so forth. Lakes are insoluble in water and are by and large utilised in items that contain oils and fats and in items that don't contain a lot of dampness like coatings of tablets, cheddar, margarine, biting gum, chocolates and so forth (Moore, Spink, and Lipp 2012; Castro et al. 2021). The Food Safety and Standards Authority of India (FSSAI) has established standards for the utilisation of lake colours in food varieties and has approved Aluminum Lake and dusk yellow FCF for use in powdered dry refreshments up to 0.04 percent by weight. Products should have a maximum of 8.3 ppm of the last drink prepared including a maximum of 4.4 ppm of aluminium content (Burrows 2009).

14.3.2 Food Colours Can Be Natural or Synthetic

Permitted colours are those that are separated from normal sources such as plants, minerals, creatures, and green growth.

14.3.2.1 Natural Colours

Red, blue, and violet are obtained naturally from beetroot, raspberries, and red cabbage; green comes from chlorophyll in leaves; and yellow-orange and red are obtained from apricots, carrots, and tomatoes (Hoegg and Alba 2007). Five natural colours—annatto, anthocyanins, beetroot, turmeric, and carmine—are generally utilised in regular groceries. Researchers have carefully examined variables influencing the strength of these and other allowed tones as well as their business applications (Tlais et al. 2020; Oplatowska-Stachowiak and Elliott 2017).

14.3.2.2 Synthetic Colours

Synthetic colours approved for use in food are more affordable and give uniform and brilliant varieties. However, their use is declining because they have been shown to have negative health impacts such as causing malignant growths, learning difficulties, and coronary illness (Downham and Collins 2000). Manufactured colours are typically severely restricted to 100 sections for each million of the last food or drink for utilisation, although some are limited to no more than 200 sections per million of the last food or drink for utilisation (Rinninella et al. 2019; Kobylewski and Jacobson 2012).

Figure 14.2 illustrates the different colours that have been permitted by the FSSAI: red, blue, green, and yellow. These colours have been subdivided further into different shades. Figure 14.3 demonstrates the various natural and synthetic colours that have been permitted by the FDA. Figure 14.4 shows the colours that have been permitted by the European Food Safety Authority (EFSA).

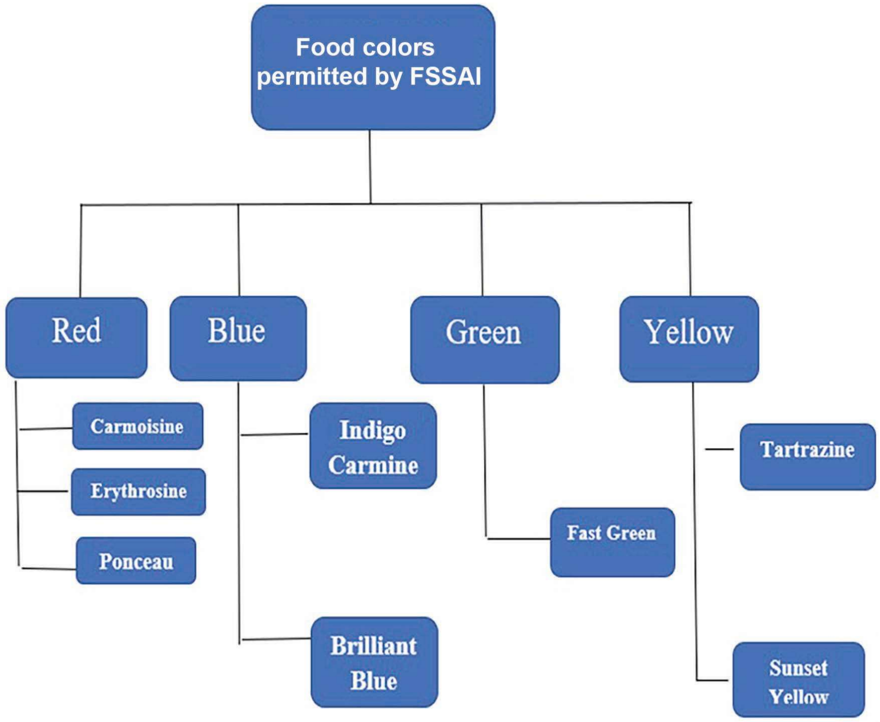

FIGURE 14.2 Colours permitted by the FSSAI.

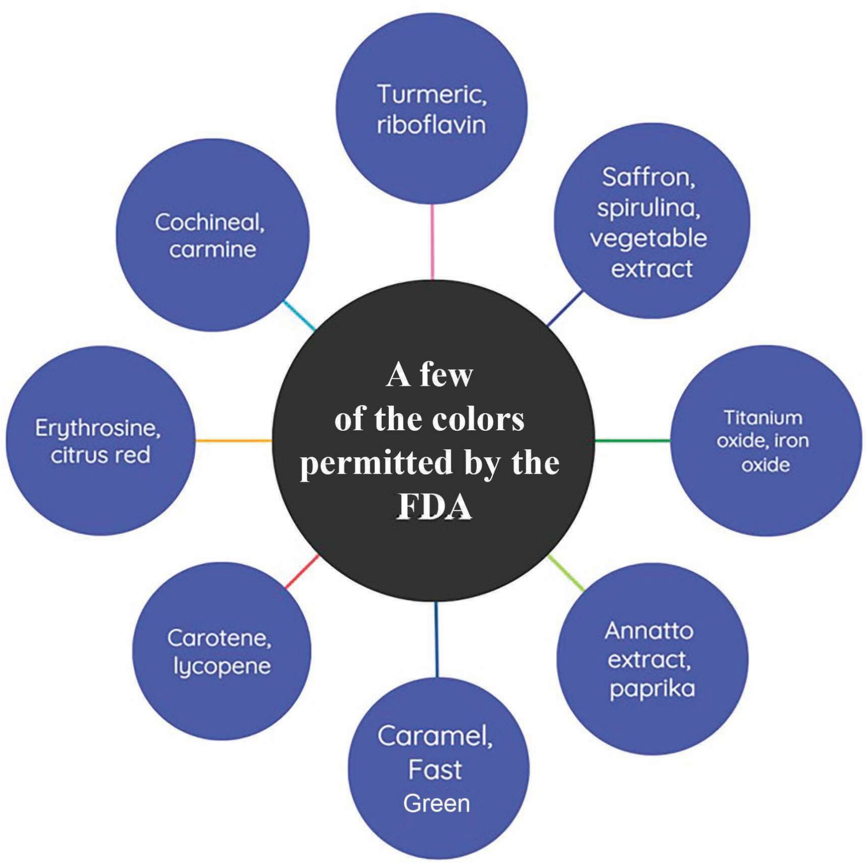

FIGURE 14.3 Some of the natural and synthetic colours permitted by the FDA.

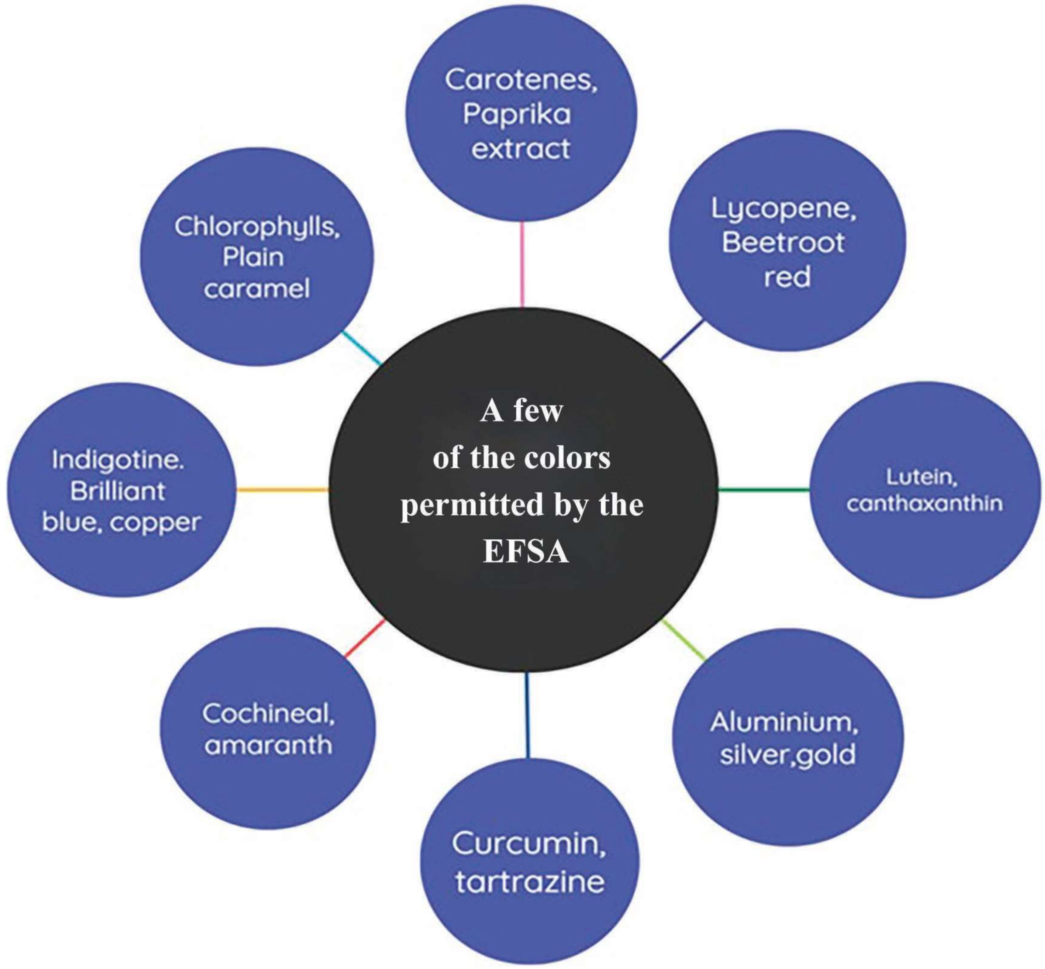

FIGURE 14.4 Some of the natural and synthetic colours permitted by the EFSA.

14.4 Toxic Effects on Health

Food colours have been determined to be more harmful to our health than any other category of food additives over the previous century. Even though they are frequently found in processed foods, most artificial food colouring has been determined to pose serious health risks (Soltan and Shehata 2012). Eating foods with artificial colours can result in inflammatory reactions in the body that activate the immune system (increases the number of white blood cells that are circulating in the bloodstream) (Oplatowska-Stachowiak and Elliott 2017).

Small molecules included in synthetic dyes have the ability to bind to proteins in our bodies. This could lead to immune system problems because the immune system fights to protect the body from them (Balakrishnan et al. 2016). Containing carcinogenic and other hazardous chemicals, Yellow 6, Yellow 5, and Red 40 are some of the most widely used food dyes that are contaminated with substances that are known to cause cancer, such as 4-aminobiphenyl, 4-aminoazobenzene, and benzidine (Okafor et al. 2016). These pollutants are present in food colours at “safe” levels, according to the FDA (Rowe 1988).

Red 3 has been known to cause animal cancer since 1990, but for some reason it is still permitted in our foods. The nutrients in food can be destroyed by synthetic food colours because of their chemical composition (Soltan and Shehata 2012); in fact, they can result in the growth of malignant tumours. Numerous types of cancer have been related to some of the most widely used food dyes: Rats and mice both developed bladder cancers after exposure to Citrus Red 2; Red 3 made rats’ thyroid cancers grow;

rats exposed to Blue 2 may develop bladder and brain cancers; immune cells found in the liver, spleen, and lymphatic system have been associated with red 40-induced reticuloendothelial tumours in mice; and yellow 6 may cause testicular and adrenal cancer in rats (Frick 2003).

Red 40 has also been demonstrated to make children hypersensitive (Abd-Elhakim et al. 2018; Arnold, Lofthouse, and Hurt 2012), Yellow 5 has been associated with hyperactivity, sensitivity, and other negative behavioural impacts in children, and research has indicated that removing artificial food colours from children's diets can lessen the signs and symptoms of attention-related difficulties and other behavioural issues (Silva, Reboredo, and Lidon 2022). Furthermore, artificial food dyes have been shown to have negative effects on the liver and other important organs' functionality; interfere with the digestive enzymes that our bodies produce to help properly break down the food that we eat; increase intestinal permeability, or "leaky gut"; and are linked to respiratory conditions such as bronchitis and asthma, as well as having negative effects on the growth of nerve cells and potentially causing a variety of other health issues (Kamal and Fawzia 2018).

14.5 Concerns with Food Colourant Additives

Riboflavin is a member of the vitamin B family (E-101), a yellow-orange solid that is only moderately soluble in water. Liver, milk, meat, and fish are the main sources of this food colouring, which is found in a wide variety of other foods. Riboflavin can be manufactured under controlled conditions using a genetically modified strain of *Bacillus subtilis* or the fungus *Ashbya gossypii*.

In several organisms, riboflavin has not been connected to any negative toxic, genotoxic, cytotoxic, or allergenic effects (EFSA Panel on Food Additives and Nutrient Sources added to Food 2015). Tartrazine (E-102) is a synthetic lemon-yellow azo dye that is mostly used as a food colouring, but studies on its effects on health have sparked debate. The most harmful outcomes have been linked to allergic reactions, hyperactivity, changes in the central nervous system, and DNA damage (Gomes et al. 2013).

A natural red colorant called carminic acid (E-120) is derived from the bug *Datylopius coccus*, which inhabits *Opuntia coccinellifer*. The bodies of these insects' pregnant females must be dried and sprayed in order to produce this colour; it is approved by the FDA for utilisation in foods, medications, and cosmetics. Carminic acid has not been shown to have any cytotoxic or genotoxic effects, but it has been connected to urticaria, asthma, anaphylactic reactions, and angioedema. Additionally, male albino rats have been shown to have impaired renal function (Amchova, Kotolova, and Ruda-Kucerova 2015).

The synthetic food colorant erythrosine (E-127) has a polyiodinated xanthene structure and is cherry-pink in colour. It is frequently used to colour children's candies and to check for tooth plates in odontology. According to the FDA, erythrosine can be used in both food and medicine; however, research has shown that erythrosine consumption is associated with altered cognition and behaviour in children that could be brought on by the suppression of dopamine receptors. Additionally, erythrosine consumption was linked in several studies to the development of chromosome abnormalities and a rise in the incidence of thyroid cancers (Haveland-Smith and Combes 1980).

As a food additive, Brilliant Blue FCF (E-133), a triarylmethane artificial food colouring, is legal; it was recently evaluated and authorised as a cosmetics colorant by the Scientific Committee on Cosmetic Products. According to the latest databases, there is no proof that Brilliant Blue FCF has any negative impacts on any organisms that have been studied in biological experiments (Cravotto et al. 2022). Figure 14.5 demonstrates the toxic effects caused by food colorants, which can be either carcinogenic or noncarcinogenic.

14.6 Food Colour Substituents

Food dye substituents are natural alternatives to synthetic food colouring agents, which have been linked to various health concerns. These natural alternatives can be derived from a variety of sources, such as fruits, vegetables, herbs, spices, and even microorganisms. Some common food dye substituents include beets, berries, red cabbage, turmeric, saffron, and fungi such as *Monascus purpureus* (Francis and Markakis 1989).

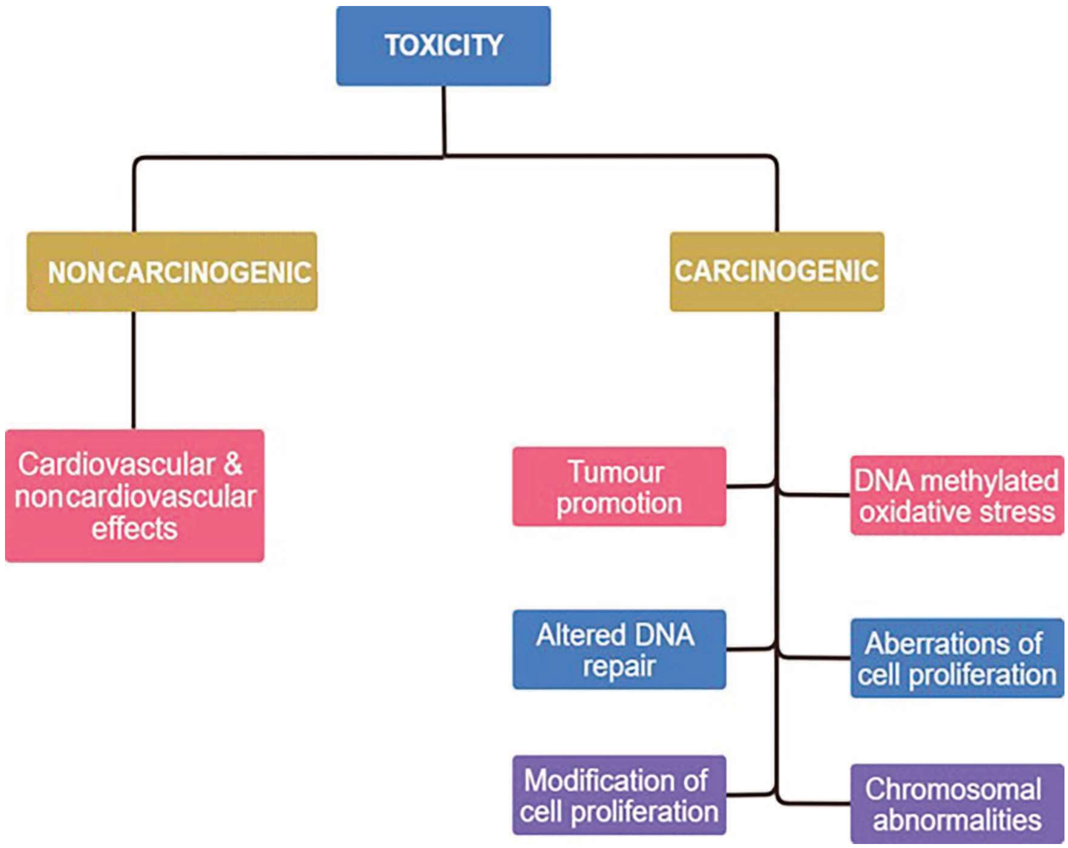

FIGURE 14.5 The carcinogenic and noncarcinogenic effects of food colours on humans.

These natural colorants can add both flavour and nutrition to food as well as providing attractive hues. They are also often more resistant to light and heat and have a wider range of pH tolerance than synthetic food colouring agents. In addition, some natural food dye substituents have additional health benefits, such as serving as antioxidants or having probiotic properties (Kaur and Kapoor 2008; Martins et al. 2016).

14.6.1 Source: Plants

Red beets, pomegranate juice, and paprika are the best substitutes for red food colouring. Purple and violet colours can be achieved by using red cabbage or berries, while pale blue can be obtained with blue spirulina (Shamina, Shiva, and Parthasarathy 2007; Francis and Markakis 1989). Spirulina, spinach, and matcha can be used as substitutes for green food colouring. Yellow shades can be achieved with the use of golden beets, saffron, or carrots.

14.6.1.1 Beets

Beets can be used as a natural food colouring to add a pink or red hue to dishes and provide flavour and nutrition. To use beets as a colouring substitute, they can be grated or chopped into small pieces, roasted, or boiled and pureed, or the juice or cooking liquid can be used as a dye (Kaur and Kapoor 2008). Beets contain the pigment betalain, an antioxidant with anti-inflammatory properties that could help prevent heart disease and stroke and that gives food a rich pink or red colour (Martins et al. 2016). They can be used in a variety of dishes, including red velvet cupcakes and chocolate cakes, and the intensity of the flavour can be adjusted by the amount of beet juice used (Martins et al. 2016; Attia, Moussa, and Sheashea 2013). It is crucial to remember that if beetroot is added too early in the cooking process, the colour can fade; it is advised to add the beetroot at the end of cooking to avoid this from happening. This antioxidant is a healthy substitute for artificial food colouring because it has anti-inflammatory qualities and could help prevent heart disease and stroke.

14.6.1.2 Pomegranate

Pomegranate juice can also be used as a natural substitute for red food colouring. High in antioxidants and phytochemicals, it provides 40% of the recommended daily intake of vitamin C (Pires et al. 2021; Basu and Penugonda 2009). To use it as a food colouring, make a concentrate by cooking a cup of freshly squeezed juice over low heat until it thickens and reduces to about ¼ of its original volume. This concentrate can then be used to colour frosting, ice cream, and other desserts a pinkish-red hue. It is important to note that assorted brands of pomegranate juice produce different shades of colour, and organic brands might be more expensive but are possibly worth it for avoiding artificial additives (Wong et al. 2002; Zha, Wu, and Koffas 2020).

14.6.1.3 Cranberries

Cranberries are a versatile ingredient that can be utilised for more than just preparing cranberry sauce over the holidays; their use as a natural food colour is one of their lesser-known applications. Because cranberries are naturally red, their pigment gives dish a vibrant pop of colour. Cranberries can make a natural food colouring that is free of artificial additives by being ground fresh in a coffee grinder or blender into a fine powder to add to foods. Cranberries can also be soaked in water and the resulting solution filtered through cheesecloth. The amount of cranberry liquid you add to your dish will have an impact on how your food turns out in terms of colour, so it may take some trial and error to achieve the precise shade you like (Babitha 2009).

14.6.1.4 Red Cabbage

Red cabbage is not only a healthy vegetable, but it also naturally colours food, giving dishes a lovely hue. Anthocyanin, a plant chemical with antioxidant and health advantages, is the purple-red pigment present in red cabbage. Simply stew a few red cabbage leaves in water for about 10 minutes to extract the colour; the resulting purple cooking water can then be used as a natural food colouring (Metting and Pyne 1986).

Red cabbage has the unusual ability to be used to make blue colouring by adding baking soda to the heating water; when using baking soda, be careful because too much can give the liquid a bad taste. As the liquid colour can sometimes be a little bitter, it is advised to use it sparingly in recipes, particularly in spicy bakes or to colour boiled eggs. In addition to giving foods a lovely purple-red tint, red cabbage offers additional health advantages (Zha, Wu, and Koffas 2020). Figure 14.6 reveals the natural substituents of artificial food dyes.

14.6.1.5 Paprika

In addition to being a common spice in many kitchens, paprika is a natural food colouring that gives foods a rich, warm tint. The distinctively spicy flavour of paprika, which is prepared from dried, ground red peppers, gives savoury meals depth and complexity, making it a fantastic choice for adding colour to savoury bakes or for use in chilli (Zha, Wu, and Koffas 2020). It is vital to keep in mind that paprika can have varied levels of heat when used as a food colouring, so those with sensitivity to spicy flavours should use it sparingly.

14.6.1.6 Berries

Berries are an excellent natural alternative to food colouring in addition to being tasty and healthy. Berries come in a variety of varieties, each with a distinctive colour that can be used to enhance meals. When

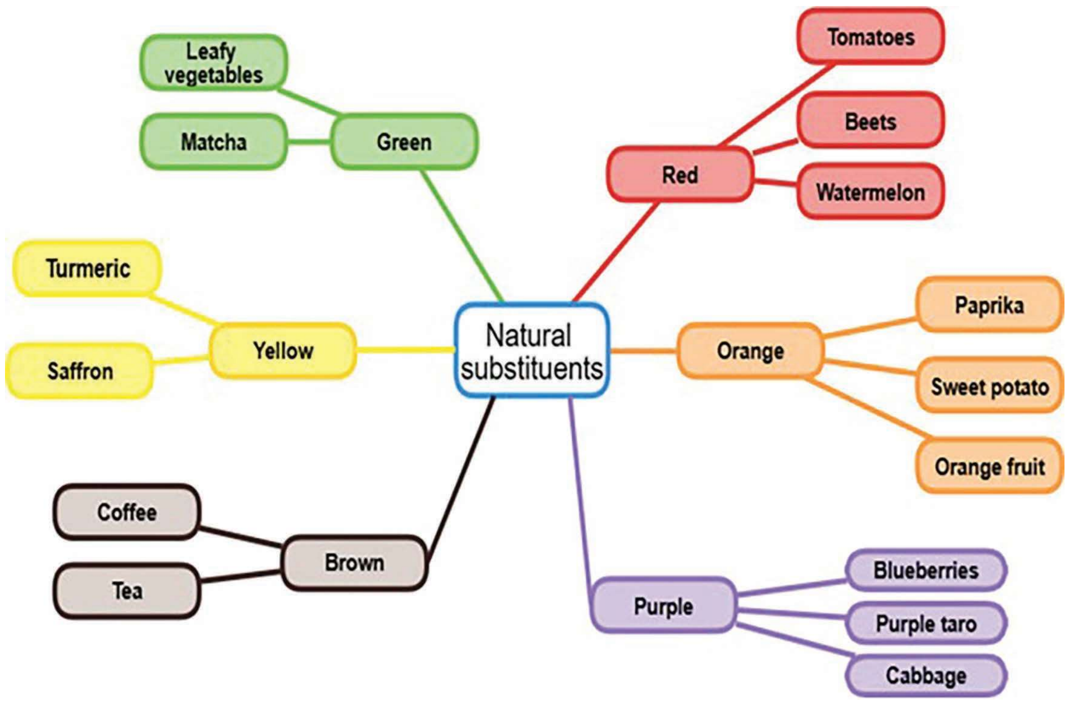

FIGURE 14.6 Natural substituents and their respective colours.

added to batter, acai berry powder takes on a deep purple hue when combined with warm water. For colouring cakes, cupcakes, and other baked products, this makes it a fantastic choice (Zha, Wu, and Koffas 2020). To provide a lovely pink or bluish-purple tint, strawberries and blueberries can be combined with icing, cake filling, or ice cream, respectively.

14.6.1.7 Dried Hibiscus

Dried hibiscus flowers can be used as a natural food colouring by grinding them into a powder and adding them to the desired dish. The intensity of the colour will depend on the amount used. Hibiscus imparts a pink or red hue to food, similar to the colours that can be found naturally in foods such as berries, bananas, grapes, tomatoes, and watermelon (Venil, Zakaria, and Ahmad 2013).

14.6.2 Source: Microbes

Microbial pigments, produced by microorganisms such as *Monascus* and *Achromobacter*, have been used to enhance the appearance of traditional processed foods in Asia (Chaudhary et al. 2022). These pigments are being studied to create stable, high-quality food colourants resistant to light and heat with a wide range of pH. Natural colourants, including those from vegetables and fruits such as saffron and turmeric, are increasingly being replaced by these pigments in food, drugs, and cosmetics. Some of these pigments may have additional health benefits, such as serving as food supplements or having probiotic or anticancer properties (Moliné, Libkind, and van Broock 2012; Zha, Wu, and Koffas 2020).

14.6.2.1 Bacteria

In Asian cuisines, bacterial pigments have been utilised for millennia as natural food colourings; however, their application in Western cuisine is relatively new. These colours are used to give food a pop of colour and make it more aesthetically pleasing. They are created by different species of bacteria. Zeaxanthin, carotenoids, canthaxanthin, and astaxanthin are a few types of bacterial pigments that are used as food colourings; these dyes are not only safe for the environment but also have probiotic health advantages.

Other bacterial pigments are being researched for use as food additives in addition to the regularly used colours. For instance, *Streptomyces coelicolor* and *Bacillus subtilis* were used to isolate a blue pigment known as actinorhodin and a brown pigment, respectively. The blue pigment's stability and nontoxicity make it an especially appealing food ingredient. The fact that bacterial pigments are organically created, environmentally friendly, and might even be healthy makes them an intriguing alternative for food colouring. Bacterial pigments are being used more frequently as food colorants and could soon overtake artificial food colouring in popularity (Nwoba et al. 2020; Garcia-Cortes et al. 2021).

14.6.2.2 Fungi

In many cultures across the world, fungi have long been employed as a natural source of food colouring. *Monascus* pigments are a popular food colouring in fermented rice in Asia. It has been established that these pigments, which are created through fermentation with the *Monascus* fungus, offer therapeutic benefits as well as giving a red or pink hue. Using the fungus *Neurospora sp*., the traditional fermented peanut-kernel cake known as "oncom" is produced in Indonesia. Its vibrant hue ranges from red to orange and yellow. Overall, using fungus as a natural food colouring is a great approach to improving food appearance while maintaining its safety and nutritional content (Trisha et al. 2022).

14.6.2.3 Yeast

In recent years, interest has grown in the utilisation of microbial yeasts as a natural source of food colouring. One such instance is the yeast genus *Rhodotorula*, which is capable of producing food-colouring carotenoids such as carotene and pigments such as torularhodin and torulene. Their poor manufacturing rate is still a problem, though.

Rhodotorula mucilaginosa strains have been modified by scientists using methods including ultraviolet-B radiation in an effort to increase pigment synthesis (Abdel-Rahman et al. 2011). Table 14.1 indicates the different microbial sources that have the ability to produce pigments along with their bioactivities and applications. Other red yeasts, such as *Rhodosporidium, Sporidiobolus, Sporobolomyces, Cystofilobasidium*, and *Kockovaella*, can also be used as a source of carotenoids in addition to *Rhodotorula*. Astaxanthin, a pigment used as a food colorant, is derived from *Xanthophyllomyces dendrorhous*. These yeasts provide a secure and organic replacement for artificial food colouring (Potter and Hotchkiss 1995).

14.6.2.4 Microalgae

Microalgae are used as food colourants, but they also have a number of other uses. For instance, certain species of microalgae are a valuable component of functional diets because they are high in vital fatty acids, minerals, and vitamins. Microalgae can be farmed sustainably and with little harm to the environment by using other companies' effluent as a source of nutrients. Microalgae are also a viable ingredient for use in natural health and wellness products due to evidence of their antibacterial and anti-inflammatory qualities. Microalgae are a flexible and sustainable choice for natural food colouring, delivering a variety of colours and maybe positive health effects (Woodward et al. 1990).

14.7 Guidelines of Different Agencies

14.7.1 India—Food Safety and Standards Authority of India

Food safety guidelines vary widely around the world, usually guided by government agencies; this section discusses a selection of the food additive regulations in operation around the world. In India, only colours and flavours approved by the Food Safety and Standards Authority of India (FSSAI) are permitted

TABLE 14.1
Classification of Microbes Used as Natural Food Colour Substituents

Food colour	Effect on living organisms	Source	Application	Reference
Astaxanthin	• Anti-inflammatory • Photoprotector • Antioxidant • Antimicrobial	• *Yeast* • *Paracoccus carotinifaciens* • *Microalgae* • *Agrobacterium aurantiacum* • *Halobacterium salinarium*	Food colourants, animal & fish food	(Jansson et al. 2018)
Arpink red	• Antibiofilm	• *Penicillium oxalicum*	Food colourant	(Kumar et al. 2015)
Beta-carotene	• Suppression of cholesterol • Anticancer • Antioxidant	• *Rhodoturula gracilis* • *Dunaliella salina* • *Rhodoturula rubra* • *Mucor circinelloides* • *Rhodoturula glutinis* • *Phycomycesblakes leeanus* • *Blakeslea trispora*	Vitamin A source, food colourant	(Sigurdson, Tang, and Giusti 2017)
Canthaxanthin	• Anticancer • Antioxidant	• *Bradyrhizobium Sepp*,	Poultry feed and salmon feed	(Hamid, Thakur, and Kumar 2017)
Monascus pigments	• Anticancer • Anti-obesity • Antimicrobial	• *M. pilosus* • *M. purpureus* • *M. froridanus* • *M. rubera*	Food colourant	(Jia et al. 2017)
Melanin	• Anti-HIV • Antibiofilm • Antimicrobial • Antioxidant	• *Saccharomyces* • *Neoforman*	Cosmetic creams, food items, eyeglasses	(Peltonen and Strachan 2020)
Prodigiosin	• Anticancer • Antimetastatic activity • Immunosuppressant • Antimalaria	• *Serratia marcescens* • *Pseudoalteromonas rubra*	Colouring agent in milk, yogurt, and carbonated drinks	(Sajjad et al. 2020)
Phycocyanin	• Cytotoxicity • Apoptosis • Anti Alzheimer's activity • Antioxidant	• *Spirulina sp*, • *Pseudomonas spp*, • *Aphanizomenonflos-aquae*	Ice cream, sweets	(Cuellar-Bermudez et al. 2015)
Violacein	• Anticancer • Antioxidant • Antiviral • Antifungal • Anti-tuberculosis • Anti parasitic • Anti protozoal • Anti-HIV • Antimalaria	• *Chromobacterium violaceum* • *Janthinobacterium lividium* • *Pseudoalteromonas tunicate* • *Pseudoalteromonas spp*	Cosmetics, textile, food industries	(Dufossé 2018)

Food colour	Effect on living organisms	Source	Application	Reference
Riboflavin	• Protection against cardiovascular diseases • Antioxidant • Anticancer • In vision	• *Clostridium acetobutylicum* • *Eremothecium ashbyii* • *Ashbya gossypii* • *Debaromyces subglobosus* • *Candida guilliermundii*	Food industry	(Dufossé 2018)
Lycopene	• Anticancer • Antioxidant	• *Sporotrichioides* • *Blakesleatrispora* • *Fusarium sp*, • *Lycopersicon esculentum*	Meat colourant	(Giovannucci 2002)

for use in food products (Nwoba et al. 2020). Specifically, the FSSAI has only approved guidelines for the use of additive to create red, blue, green, and yellow food colourings and their standard requirements (Woodward et al. 1990). These requirements are discussed in this section.

14.7.1.1 Erythrosine

The total dye concentration of an erythrosine sample after drying at 1051 °C for two hours should be at least (NLT) 87% by mass. At 135 °C, the loss on drying should not exceed 13% by mass (NMT). The water-insoluble content should be less than NMT 0.2% by mass. The extractable substance from ether should be NMT 0.2% by mass. The concentration of inorganic iodide as sodium iodide should be NMT 0.1% by mass. Except for fluorescein, other secondary colouring materials should be NMT 4% by mass (Tuli et al. 2015); fluorescein NMT should be 20 mg/kg. Except for colouring matter, organic components should be NMT 0.2% by mass. NMT values for lead, arsenic, zinc, and heavy metals should be 10, 3, 50, and 40 mg/kg, respectively. Copper, mercury, and chromium should be absent from the food product. Aromatic nitro chemicals, cyanides, aromatic hydrocarbons, and aromatic amines should also be avoided.

14.7.1.2 Beta-Carotene

Carotene crystallises as either dark violet hexagonal prisms from a benzene methanol solution or as red rhombic, almost quadratic plates from petroleum ether. Whereas methanol and water are essentially insoluble, benzoene, chloroform, and carbon disulfide are soluble; cyclohexane, ordinary hexane, petroleum ether, and oils ether are somewhat soluble. The maximum absorption of a dark blue solution of -carotene in chloroform with antimony trichloride should occur at 590 m wavelength. The maximum limit of metallic impurities should be as follows, and the minimum purity of -carotene should be 96.0%: 10 ppm of lead, 3 ppm of arsenic, and 40 ppm of heavy metals (Dsouza, Pischel, and Nau 2011).

14.7.1.3 Chlorophyll

Chlorophyll, also known as C. I. Natural green tree, is a plant-based green pigment that is used in food colouring. For usage in food products, a chlorophyll solution in ethanol should generate a bright red fluorescence with a blue colour (Meena et al. 2022). When 10% methanolic potassium hydroxide is added to a chlorophyll solution produced with green ether or petroleum ether, it should soon turn brown and then return to green. If the chlorophyll is treated with alkalis, this test yields a negative result (Vaclavik and Christian 2014).

The following are the limits for metallic contaminants in chlorophyll: Lead should be NMT 10 ppm, arsenic should be NMT 3 ppm, zinc should be NMT 50 ppm, and copper should be NMT 30 ppm. NMT 10% by weight for total combined pheophytins and magnesium complexes. The residual solvent level, such as methanol, ethanol, acetone, 2-propanol, and hexane, should be NMT 50 mg/kg. Dichloromethane's residual solvent content should be NMT 10% (Vaclavik and Christian 2014).

14.7.1.4 Riboflavin

Riboflavin is a yellow to orange-yellow colorant that is allowed for use in food goods. If it is to be used safely in food, it must meet the following requirements: In transmitted light, 1% riboflavin solution in water should be pale greenish yellow; in fluorescence, it should be deep yellowish green. This bright fluorescence should disappear when mineral acids or bases and sodium dithionite are added (Amchova, Kotolova, and Ruda-Kucerova 2015).

The maximum absorption of a riboflavin aqueous solution should be 220 to 225, 266, 371, and 444 m. Riboflavin has a minimum purity of 97%. The maximum limit for metallic impurities should be NMT 5 ppm for arsenic. MT 20 ppm lead should be used. Aside from the colours mentioned above, FSSAI maintains standards for Tartrazine, Sunset Yellow, Indigo Carmine, Caramel, Annatto, and others.

14.7.1.5 Flavouring Agents Forbidden by FSSAI Laws

The following additives are not permitted as flavour solvents by the FSSAI: Tonka bean (*Dipteryx odorata*), coumarin, and dihydrocoumarin; cinamyl anthracilate; isothujone; thujone; estragole; ethyl methyl ketone; ethyl-3-phenylglycidate; methyl eugenyl ether; diethyleneglycol; isosaffrole and saffrole; and monoethyl ether (Dsouza, Pischel, and Nau 2011).

14.7.2 United States—Food and Drug Administration

According to the US Federal Food, Drug, and Cosmetic Act (FD&C), a substance that satisfies the definition of a colour additive must be obviously unimportant in terms of appearance, value, marketability, or consumer acceptability for the substance to be exempt from Section 721 of the Act. Simply explained, an additive is a colour if its purpose is to change the appearance of food (Woodward et al. 1990).

The FDA must authorise an additive's usage as a colour before it can be used in food. Exempt colour additives are manufactured variations of naturally occurring colorants or are predominantly sourced from plants, animals, or minerals. These are artificial colour additives; therefore, even if batch certification is not required, they must nonetheless adhere to the composition and purity standards outlined in the Code of Federal Regulations. Certain food product classifications or usage restrictions apply to some of the colours that are exempt from certification. Reviewing 21 CFR Section 73 for these limitations is essential (Dsouza, Pischel, and Nau 2011).

In the United States, colour additives must be labelled. In the ingredient list, certified colours must always be stated by name, although number and FD&C prefix are not necessary. The FDA also allows for alternative, equally useful nomenclature, if colour usage is explicitly stated. Colour description is excluded from the following alternatives that stipulate that declarations must be made by name. The exempt-from-certification colours cochineal extract and carmine must now be mentioned by name. Although the term "natural colours" is often used in business, it is not permitted to use it on ingredient declarations. No matter where colour originates from, according to FDA standards, no additional colour is considered natural unless it is "native to" the food product itself, such as strawberry ice cream that has been tinted with strawberry juice (Meena et al. 2022).

14.7.3 European Union—European Food Safety Authority

There are 26 member countries and five candidate nations in the European Union. The existing regulatory framework was developed by the EU over a long period of time, although the first additive directive was adopted in 1962 using an E-number system of classification. Other instructions for emulsifiers, antioxidants, and preservatives were given. The member states can still set the maximum allowed levels of chemicals and the permitted foods under this agreement (Vaclavik and Christian 2014).

Managing risk for food additives falls within the purview of the Directorate General for Health and Consumer Protection. Specific risk assessments for the security of food ingredients are examined by the European Food Safety Authority (EFSA). The EFSA comprises two panels. The panel on food additives and nutrition sources added to food (ANS), which does not include flavourings and enzymes, addresses safety issues regarding the use of food additives, nutrient sources, and other chemicals purposefully added to food.

The ANS panel applies what it calls the "precautionary principle" and a low-risk philosophy, under which it is better to be safe than sorry. Guidance Notes on the Classification of Food Extracts with Coloring Properties, Version 1, were released by the Standing Committee on Food Chain and Animal Health on November 29, 2013. These recommendations ought to be examined in light of pertinent legal provisions, particularly Regulation (EC) No. 1333/2008 on food additives. These advisory notes are not meant to be legally binding and do not reflect the commission's official position (Amchova, Kotolova, and Ruda-Kucerova 2015). The guiding notes provide a decision tree for determining whether a substance is a food additive, a flavour enhancer, or a colourant (Vaclavik and Christian 2014; Amchova, Kotolova, and Ruda-Kucerova 2015). Figure 14.7 presents the EU's decision-making process for permitting a new colour. It also presents the regulations for the particular dye that has been permitted.

14.7.4 Mexico

The Mexican Norma Official Mexicana (NOM), or Official Mexican Standard, is the list of laws and rules that are required by the government of Mexico for a variety of activities. In the absence of a NOM for food, Codex, EU, or US rules can be used. Currently, there is no NOM for confectionery products (Vaclavik and Christian 2014).

14.7.5 China—National Food Safety Standard-Standard for the Use of Food Additives

Colour laws in China are governed by GB2760–2011-National Food Safety Standard-Standard for the Use of Food Additives (Keener 2022); on June 20, 2011, the most recent edition went live. Colours are registered, and any new colours require the provision of toxicity information. Each colour is individually questioned on how much it is used (Vaclavik and Christian 2014). Colours have their own purity standards that adhere to the Codex recommendations. There are, however, some strange import regulations that apply when mixing colours with other components. GB 26687–2011 The National Standards for Food Safety, General Rules Regarding Compound Food Additives prohibits the total quantity of lead in food colours to 2 ppm and the combined level of arsenic to less than 2 ppm despite the restriction on the individual additive (Keener 2022; Vaclavik and Christian 2014).

14.7.6 Japan—External Trade Organization of Japan

Japan has developed its own laws based on its own thinking, just as the United States. The External Trade Organization of Japan has released the Food Sanitation Act Specifications and Standards for Foods, Food Additives, and Other Ingredients in English. The statute lists the colours and other chemicals that are acceptable. Colours can be categorised as existing food additives, food additives without usage restrictions, food additives with usage guidelines, and compounds that are typically provided as food but are

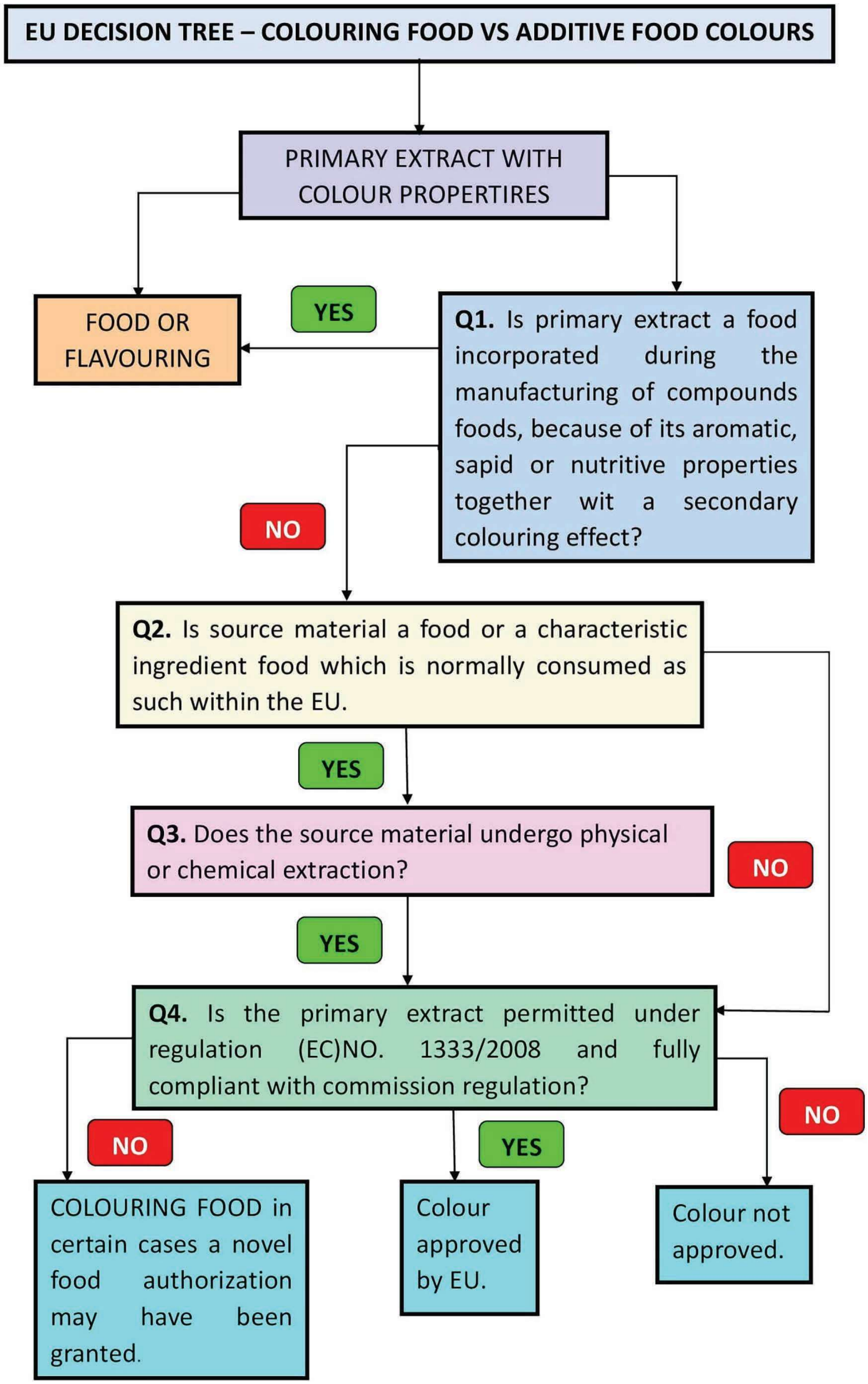

FIGURE 14.7 EFSA decision tree for approving new food colours.

used as food additives. Additionally, Japan has two distinct food categories, Food with Nutrient Function Claims and Food for Specified Health Uses, in addition to conventional food category classifications (Shimizu 2003; Amchova, Kotolova, and Ruda-Kucerova 2015).

14.8 Conclusion

This chapter describes how food colours are utilised in the food and beverage industries for a variety of purposes. The role of food colours varies depending on the product. They contribute to improving appetite, generating revenue, and enticing customers. However, although they appear appealing to the eye, artificial food colours have some significant detrimental impacts on intake. In response, nations worldwide developed guidelines and standards for additives approved for use as food colourants. It is clear that government agencies globally have addressed the concerns with using food additives to enhance the colours of foods.

Although colours remained an effective marketing tool, artificial food colours were replaced with colours derived from natural sources such as plant pigments and microorganisms; these were discovered to be safe and effective in large quantities. However, the use of synthetic colours could not be entirely prohibited. Instead, manufacturers and producers can continue to use artificial additives, but they must adhere to the government agencies' rules.

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CHAPTER

3 Green carbon nanomaterials and their application in food, agriculture, and biomedicine

Ch S.H. Sudheshna[1], □yothika Meenakshi Kambhampati[1], Chinthakindhi Samanth[1], Gali Chaitra[1], Harika Reddy Pulipelli[2], Bhushan Vishal[3], C. Nagendranatha Reddy[1], Sanjeeb Kumar Mandal[1], Divya Prema Suroju[1], Dinesh Chand Agrawal[4], Bishwambhar Mishra[1,*]

[1]Department of Biotechnology, Chaitanya Bharathi Institute of Technology, Hyderabad, Telangana, India; [2]Department of Microbiology and Molecular Genetics, School of Medicine, University of California, Irvine, CA, United States; [3]School of Biological Sciences, Nanyang Technological University, Singapore; [4]School of Life & Basic Sciences, Jaipur National University, Jaipur, India;

[*]Phone: 040-24193276; Email Id: bishwambhar_biotech@cbit.ac.in

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3.1 Introduction

Nanomaterials are substances having at least one exterior dimension that range within 1 and 100 nm. A “nanomaterial” is any substance that contains internal or exterior structures that are on the nanoscale. A nanoparticle is a tiny, three-dimensional object at the nanoscale. The term “nanotechnology” refers to the synthesis and use of materials having structural qualities intermediate with at least one dimension falling between 1 and 100 nm, between those of atoms and bulk materials [1,2]. Nanometric materials have unique features that set them apart from bulk materials or atoms. American physicist Feynman, who was a 1959 Nobel Prize winner, was the first to propose the concept of nanotechnology. Due in large part to the creation of novel approaches for their characterization and adaptation as well as the assembly of nanomaterials, nanoscience and technology have seen significant growth over the past 10 years [3].

There are several cutting-edge methods available right now for producing nanoparticles, nanotubes, and their assemblages. Certain semiconductor, metal, and other material nanostructures’ size-dependent electrical, optical, and magnetic properties are now better known. In addition to the well-established methods of spectroscopy, crystallography, and electron microscopy, scanning probe microscopies generated useful instruments for studying nanostructures [4,5]. Innovative

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methods for producing decorated nanostructures are constantly being developed, along with fresh ideas for devices and manufacturing procedures. Nanostructures are so small that they may tolerate highly harsh treatment, making them ideal for computer simulation and modeling [3].

3.1.1 Nanomaterials of various elements

Nanoparticles are extremely small compounds with sizes ranging from 1 to 100 nm that have been produced as a result of the advancement of science. Due to their differences from their elemental bulk equivalents and frequent occurrence of unexpected but intriguing properties, these nanoparticles are of enormous scientific interest. For instance, both gray silicon and yellow gold appear red at the nanoscale due to their surprising optical properties. Due to their broad surface versus volume ratio, they are also far better at absorbing solar energy and forming superior catalysts. Nanoparticle addition can also enhance the properties of numerous commonplace things. In contrast to the bulk material, zinc oxide nanoparticles, for example, have better UV-blocking properties, and titanium oxide nanoparticles offer a self-cleaning property [3].

Carbon in the form of nanotubes is used in integrated circuits for electrical parts and composites for automobiles and sporting goods. Due to their two-dimensional hexagonal lattice of bent and fused carbon atoms, they have exceptional tensile strength and mechanical stiffness [3]. Nanosized aluminum can be used as a desiccant to dry gases, take fluoride out of different media, and take in hydrocarbon pollutants from the air. It is also used as a sorbent for radionuclides and metal ions in solutions from nuclear power plant wastewater. Depending on the particle size, titanium oxide can be found in sunscreen, cosmetics, paints, and coatings. Nearly two-thirds of all pigments, including the food coloring E171, include the naturally occurring oxide, which can help eliminate impurities from drinking water. It is used as a whitening and brightening agent [6].

Two of the many potential uses for nanoscale iron are a smart fluid for optic cleaning and the elimination of pollutants such as PCBs and chlorinated organic solvents from groundwater. It features a large surface-to-volume ratio, which makes it potentially beneficial in labs and for medical purposes [4]. Cobalt oxide nanoparticles may be advantageous for lithium-ion batteries because they can quickly and irreversibly incorporate lithium into their structure. Because of how easily they may enter cells, they can also be used in medicine for gene therapy, hyperthermic therapy, drug administration, and electronic gas sensors for the detection of acetone, toluene, and other organic vapors [5].

The use of copper as a coloring agent dates back to the ninth century when it was first used to color glass and ceramics. It is employed in biomedicine because of its catalytic, antifungal, and antibacterial characteristics. It might be utilized as a biosensor or electrochemical sensor [3]. Nanosilver is increasingly being used in fabrics, clothing, and food packaging due to its antibacterial properties. The focus of biological research is on its application as a catalyst and as a transporter for both

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small therapeutic compounds and large macromolecules, such as chemotherapeutic medicines. Cerium is a rare earth metal that is silvery white, soft, ductile, and blade-cuttable. Cerium oxide is a pale yellow-white powder that is produced when cerium is oxidized and can be utilized in electronics, biomedical supplies, energy, and fuel additives. Other uses include acting as a catalyst to change ferrous impurities with a green tint into colorless ferric oxides, which decolorizes glass in optics. It also possesses antibacterial and antioxidant effects [7].

A colloid of nanoparticles and suspensions of nanoparticles in water are the two most common forms of platinum. Optics, medicine, enzyme immobilization, electronics, and catalysis are a few possible applications. Similar to platinum, nanogold can also be found as a suspension or colloid. It has potential applications across a variety of disciplines, together with electron microscopy, materials science, nanotechnology, and electronics. Fig. 3.1 illustrates elemental sources of different nanoparticles.

3.1.2 Types of carbon nanoparticles

One of the minerals that is most prevalent and numerous on the earth is carbon. The small molecules required for existence are carbohydrates, proteins, DNA, and others. There are numerous allotropes of pure carbon. Diamonds and graphite are the two the best-known crystal forms of carbon in nature. Allotropes involving amorphous carbon comprise fossil fuels, charcoal, and lampblack. Carbon nanomaterials take advantage of carbon's extraordinary characteristics. In the year 1980, nanoparticles made of carbon (CNPs) were first discovered. The amorphous carbon

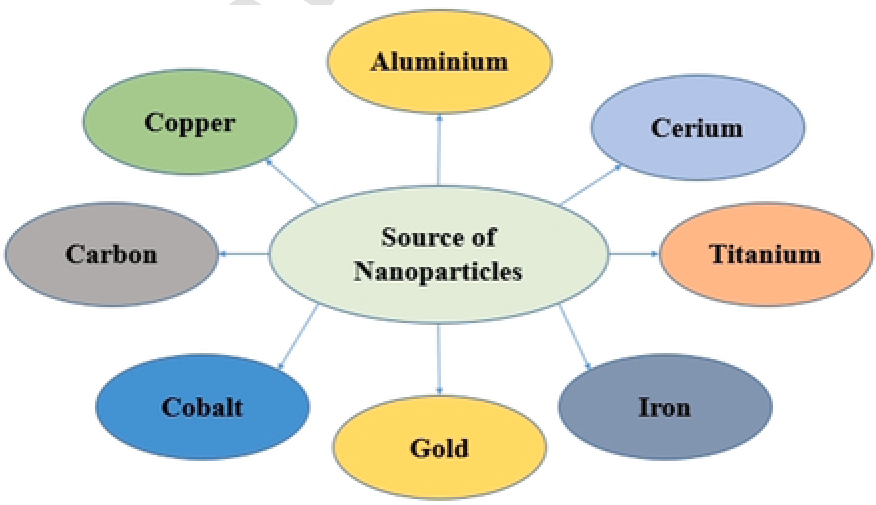

FIGURE 3.1

Elemental sources of nanoparticles.

nanoparticles (CNPs) include nanoscale carbon elements, carbon nanoparticles, as well as carbon dots. Graphene, graphene quantum dots (QDs), carbon fullerene carbon nanotubes, carbon nanohorns, and nanodiamonds are also among them [8]. CNPs have extraordinary mechanical qualities (extreme stiffness, strength, and toughness), great stability, outstanding, low toxicity, and good biocompatibility because they are made of pure carbon. They are very hydrophobic as a result of their SP^2 hybridization. CNPs have undergone extensive research, left the lab, and been mass-produced. Fig. 3.2 describes various types of carbon nanotubes

3.2 Synthesis of various carbon nanomaterials

The principal methods for manufacturing graphene in large quantities are raw graphite can be exfoliated chemically or plasmatically, mechanically, via chemical vapor deposition, or by epitaxially growing graphene on the silica side of silicon carbide. Graphene can be obtained in three ways: as a derivative, by breaking up carbon nanotubes, or by evaporating fullerene. Graphene is oxidized to create the two most prevalent graphene derivatives, which are graphene oxide (GO) along with diminished graphene oxide (rGO). $KMnO_4$ and the protonated solvents (sulfuric acid, nitric acid, or their mixtures) are used in these processes to treat graphene. As a result, graphene or its carboxyl or hydroxyl groups form covalent bonds. A

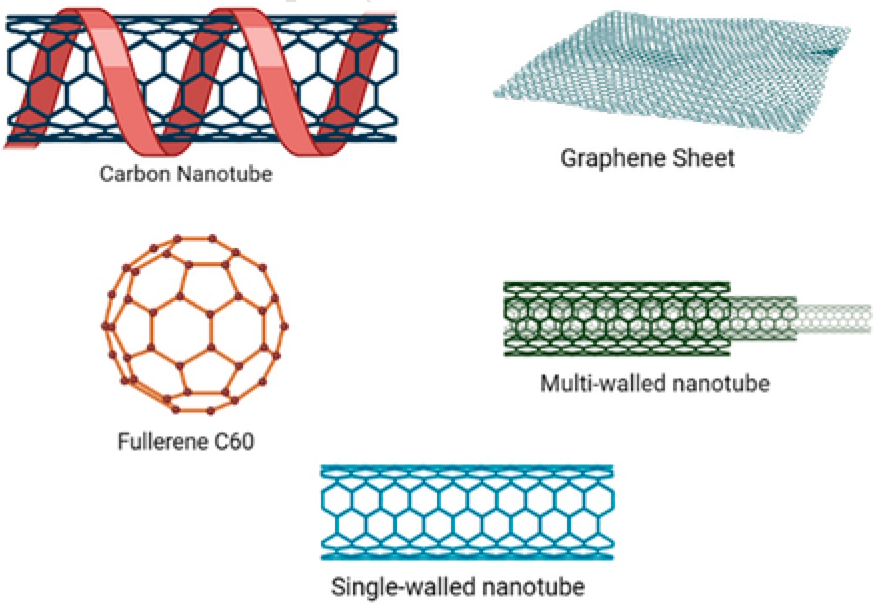

FIGURE 3.2

Types of carbon nanotubes.

great deal of the functional groups associated with oxygen are subsequently eliminated in a reduction to generate rGO by a variety of procedures, include treating using vitamin C or hydrazine hydrate. Rolling graphene sheets produces carbon nanotubes (CNTs), which are nanoscale particles with cylindrical tubular shapes and a diameter of a few nanometers. There are two varieties of CNTs: single-walled and multiwalled, based on the number of graphene sheet layers. Pulsed laser ablation, arc discharge, and chemical vapor deposition (CVD) are the most frequently utilized processes for making carbon nanotubes. The CVD uses carbon consisting of precursor gases, such as CO_2, C_2H_2, C_2H_4, and other hydrocarbons. During CVD, the temperature varies between 350 and 1000°C [8]. A number of variables, considering the duration of the nature, size, reaction, temperature, as well as catalytic size and velocity of the reaction gas, affect the growth of CNTs. The arc's cathode and anode electrode discharge technique consists of two graphite rods. The electrodes are then exposed to a direct current arc voltage while submerged in helium, an inert gas. CNTs and fullerenes are produced using this technique [8].

On the cathode, MWCNTs are formed, while inside the chamber, fullerenes are formed as soot. A pulsed laser is a very promising method for ablation of graphite. It quickly and efficiently creates a product of exceptional quality in the appropriate form and size without the need for a catalyst or vacuum [9].

3.2.1 Disadvantages of synthesizing nanoparticles using conventional methods

The CNPs are often created by a disaggregation-based method of an initial bulk carbon material or based on carbon-containing molecule-based particle nucleation and growth [10]. In the initial case, the precursor is etched using only chemical processes, electrochemical processes, mechanical processes, or laser assistance. N-methyl pyrrolidone (NMP), used in the production of graphene by the chemical exfoliation method, is toxic to the reproductive organs and an eye irritant [11]. The chemical exfoliation method's other active ingredient, *N*,*N*-dimethylformamide (DMF), may be hazardous to several organs. The PPM approach uses organic compounds, which have the potential to be harmful. The sol–gel process also uses hazardous chemicals, which present serious risks [11]. The exterior quality, metal catalyst and/or graphite content, UV exposure, dispersion properties, and propensity to assemble a result of intense forces of Van der Waals are all important factors that affect how these particles behave. Furthermore, because some species, such as rats, are more sensitive to particles, it is challenging to extend the findings to humans due to species disparities in studies. Regarding the impact on human cells, it has also recently been shown that highly pure Single-Walled Carbon Nanotubes (SWNTs), which include just minute amounts of graphite and metal catalysts, are less harmful to human macrophage cells than less-purified SWNTs [12]. SWNTs can also stop the proliferation of human cells by killing cells and lowering cellular adhesion, according to a study [13]. Recent research has shown that both DWNT and SWNT activate the human serum complement system through both traditional

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and unconventional mechanisms [14]. Carbon nanotubes' ability to activate complement results in the production of inflammatory peptides, which may encourage harmful consequences including inflammation and granuloma development. Actually, it is unknown to what extent the biological milieu in which carbon fullerenes may be maintained for years will be affected by continuous exposure to them. These compounds' behaviors can be altered by chemistry and surface changes, making them cytotoxic. Recent research has shown that the surface modifications—whether caused by irradiation, derivatization, or functionalization—of C60 fullerenes are the primary cause of their cytotoxicity. According to Sayes et al., human neural astrocytes, human dermal fibroblasts, and liver cancer cells are all lethal to water-soluble C60 Fullerene aggregates [15]. They cause lipid peroxidation, which interferes with proper cellular activity. Its surface derivatization affects its cytotoxicity. They may produce superoxide anions, which may lead to cell death because of membrane damage.

3.3 Green synthesis of carbon nanomaterials

Nanotechnology has the capacity to profoundly transform lifestyles, occupations, and entire economies because of its applications that cut across scientific disciplines, including electronics, medicine, sophisticated manufacturing, and cosmetics. However, many of the practices and materials currently in use not only consume limited resources but also produce hazardous waste. Thus, the integration of green chemical techniques with nanotechnology applications is essential for the future of nanotechnology [16]. Many of these so-called "green nanotechnologies" are now making the leap from the lab to commercial use, but there are still many challenges that need to be solved.

A commercially viable synthetic process for creating luminous carbon nanoparticles with quick clearing properties is demonstrated in an experiment conducted by Wu et al. An environmentally friendly method is being investigated that involves quick carbon nanoparticle surface passivation utilizing organic macromolecules (such as polysorbate or polyethylene glycol) without the use of solvents. Commercial food-grade honey is introduced to create naked carbon nanoparticles [17].

The existence of baked lamb with luminous carbon nanoparticles was verified in a different investigation by Wang et al. It was found that baked lamb produces bright blue fluorescence under UV light by fluorescence nanoparticles composed of carbon that have a 10% fluorescent quantum yield. The nanoparticles have a diameter of about 2.0 nm and seemed fairly spherical. The surface of nanoparticles is covered in carboxyl, hydroxyl, and amino groups. The reduction–oxidation cycle is thought to be used by these nanoparticles to serve as a fluorescence sensor for glucose detection [18].

In a study by Kumar et al., Lassi, a drinkable yoghurt, was microwave-irradiated to produce carbon nanoparticles (CNPs). According to the findings, CNPs had an average size of 12.58 0.60 nm and a zeta potential of 24.62 0.15 mV [19].

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Section 3.1 has covered the green fabrication techniques for various types of carbon nanoparticles.

3.3.1 Fullerenes synthesis

Ferrocene can be used in the composite as a catalyst and a source of magnetic nanoparticles that are easily separated by an external magnet, after removing AB25 or MB dye using an adsorption procedure. This method of making functionalized magnetic fullerene nanocomposites (FMFNc) is simple, one-step, and environmentally friendly [20]. The 60-fullerene substrate was treated with sodium hydroxide in a water/ethanol solution and added 5-aminolevulinic acid to create two water-soluble fullerene nanomaterials [21,22]. Mikheev et al. proposed a sustainable, scalable, and green strategy for producing AFD C60, C70, and endohedral metallofullerene GdC82 in aqueous fullerene dispersions, as well as C60Cl6, C70Cl10, supramolecular derivatives, and ester-like compounds of them, totaling 10 fullerene species [23]. For the first time, pristine fullerenes without addends were prepared for dispersion using an immersed ultrasonic probe. For the preparation of AFD employing an immersed probe, direct sonication, and ultrasound-assisted solvent exchange were also explored. When compared with an ultrasound-bath-assisted technique, the average amount of time needed to prepare an AFD is reduced by 10–15 times, although the final fullerene concentration in AFDs is still only an up to 80 ppm, a few ppm. Continuous stability, a nanocluster with an average diameter of not greater over 180 nm, plus a surface that is negative charged having a zeta potential of up to −32 mV were all characteristics of the aqueous dispersions. The total anionic and cationic composition of the samples was investigated using inductively coupled plasma atomic emission spectroscopy in conjunction with inductive and chromatographic methods [14].

3.3.2 Carbon nano-onions synthesis

As the catalyst, 30% (w/v) NaOH is combined with tomatoes as that of the carbon source. A straightforward carbonization process can produce water-soluble C-onions. The production of reductively synthesized covalent modified carbon Nano-onions (CNOs) required the utilization of novel alkali-metal CNO intercalation compounds [24]. It has been claimed that a revolutionary method for producing extremely brilliant CNOs in a matter of seconds involves the microwave pyrolysis of fish scale debris [25].

3.3.3 Carbon □uantum dots synthesis

Building up carbon dots has recently become more and more environmentally friendly thanks to the usage of biomass. The economical and free strategy of producing carbon quantum dots from neem leaf (*Azadirachta indica*) extracts has been demonstrated utilizing a one-pot hydrothermal procedure [26]. CDs can be made

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environmentally friendly by employing hydrothermal (or solvothermal), using the microwave or a dry heater. The most frequent source of substrate for CD production is plants, though purified renewable materials such citric acid or amino acids have also been used. For the creation of carbon dots, there have been uses for a number of microorganisms, notably yeast, bacteria, and algae as green precursors. Adenosine disodium triphosphate was used to create phosphorus and nitrogen codoped carbon dots, which fluoresced vivid blue when exposed to UV light. Bioactive carbon dots can also be made from substances. Drugs and other bioactive compounds have also been utilized in the creation of CDs [16].

3.3.4 Carbon nanotubes synthesis

Coconut shell is a rich supply of potential synthesis starting points of carbon nanotubes, which is necessary to satisfy the requirements of green chemistry. Initially, the structure of the result of burning coconut shells is similar to that of an allotrope of graphite. The coconut shell–based calcining product is produced using a one-step water-assisted process. This process involves heating the coconut shell to extreme temperatures of around 600°C in an unfinished furnace without oxygen in order to produce graphite flakes. The resultant graphite is heated to a temperature of 700°C while also making distilled water. The resultant reddish-hued graphite is submerged in cold water and allowed to sit there for a few hours at temperatures exceeding 700°C. To remove the water later on, the product is dried for 24 hours at 60°C. The result is a carbon nanotube–based black powder [27]. By heating an aqueous solution of graphene oxide and carbon nanotubes with vitamin C to create supercritical carbon dioxide, carbon nanotube and graphene hybrid aerogels are created. In a recent study, carbon nanotubes were created using a sustainable precursor derived from coconut oil. This environmentally friendly method has benefited from being the simplest way by using the chemical vapor deposition process. Iron is also used as a catalyst to accelerate the formation of carbon nanotubes on the precursor.

3.4 Applications of green nanomaterials

3.4.1 Food industry

As processed food has become so popular among humans, the packaging of food has received significant attention. However, the current focus is on the production of food packaging materials, which requires the use of chemicals, water, petroleum, minerals, and other resources. Traditional methods for identifying bacterial infections and toxins need specialized equipment, and trained personnel and are time-consuming and labor-intensive. Additionally, the food business is being burdened greatly by the high costs associated with analysis and monitoring systems. Nanotechnology has been a fascinating field in recent years for addressing issues connected to food safety. It is difficult to keep food free from bacterial development for a lengthy period of time. Therefore, scientists are making use of the diverse uses of

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carbon nanomaterials to address these difficulties. Most often, CNM is in charge of providing assistance in the form of carbon dots, carbon nanotubes, graphene, activated carbon-based nanocomposites, etc., mostly in active food packaging and adulterant testing [27].

CNMs work to maintain security by resolving several food sector domains. Throughout processing, manufacturing, transportation, and preservation, the product's quality and safety must be maintained through the use of food packaging. Polystyrene, polypropylene, and polyethylene terephthalate are examples of petroleum-based plastics that have been used for a long time in food packaging to protect the contents from tampering and contamination, as well as because they are useful for storage and transportation. However, due to its limitations in protecting food from environmental effects, packaging constructed of plastic materials cannot entirely guarantee the food's purity and safety. Additionally, notably harming the environment are nonbiodegradable plastics, which ecosystem and that pollution from microplastics and Nano plastic particles is getting worse [27].

A key concern in food safety is the identification and quantitative study of bacteria. Traditionally used techniques necessitate prolonged culture times, highly trained personnel, or particular components for each variety of bacterium to be recognized. The sensor arrays use a number of cross-reactive receptors to provide a quick, affordable, and easy method. Due to its exceptional optical qualities, which include light persistence, photobleaching tolerance, photoluminescence, quick functionalization, and great biocompatibility, this compound makes a great raw material for sensors. Fluorescence analysis has a lot of potential for food security because of its many advantages, including quick results production, low cost, simplicity of use, and high sensitivity. It has been claimed that it is simple and effective to build a CD-based fluorescence sensor array with several receptors functionalized. CDs have developed three separate types of receptors that can bind to diverse bacteria: boronic acid, polymyxin, and vancomycin because different bacterial surfaces have various physicochemical qualities. Due to their reliability, economy, sensitivity, and quick analysis, CNT biosensors hold promise for food monitoring. In food goods, they might find many specimens. However, due to the diverse chemical and biological makeup of food samples, it can be difficult to identify a particular constituent when complex settings are at play. Therefore, proper utilization of Aptamers or other substances with high selectivity and affinities is crucial, aside from specific reactions with certain molecules. Furthermore, it is necessary to build more resilient to construct a dependable quenching or recovery system for fluorescence for more precise measurement, use CDs, or use them in conjunction with other nano methods. The ideal strategy for achieving this is a green strategy. An SWCNT biosensor was created by scientists for the purpose of identifying *Staphylococcus aureus*, which is among the most typical causes of gastroenteritis brought on by eating tainted food [27].

The Wang et al. experiment proved that roasted lamb contains luminous nanoparticles that resemble CDs. These nanoparticles were relatively durable against pH, high ionic strength, and photobleaching and produced a strong blue

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light when exposed to UV radiation. These nanoparticles' many reductive groups could be subject to hydroxyl radical oxidation. They might potentially serve as sensors for the fluorescence of glucose [27]. The intrinsic luminosity of the extinct *Ctenopharyngodon idella* fish scales was confirmed by fluorescence microscopy, the spectrum of fluorescence's excitation and emission, and absorption. Fish scales made from leftover meals were used as precursors to provide a quick, affordable, efficient method for producing a huge amount of fluorescent carbon nanoparticles for Fe^{3+} sensing [18].

It has been demonstrated that the hydrothermal treatment of pomelo peel results in fluorescent CPs. The benefits of simplicity and cost-effectiveness come from the fact that CPs don't need to undergo any additional chemical alterations. The application of such precise CPs has been investigated for label-free identification of Hg^{2+} ions with a limit of detection as low as 0.23 nM. The great specificity for the Hg^{2+} is one such illustration, feature of this sensor device [28]. The production with a nitrogen concentration of 6.88% fluorescent nitrogen-doped carbon nanoparticles (FNCPs) was made simple, environmentally friendly, and affordable by hydrothermally treating strawberry juice in a single pot. The highest emission of the as-prepared FNCPs had a quantum yield of 6.3% at 427 nm and was selectively inhibited by Hg^{2+}. In order to effectively detect Hg^{2+}, this offers a green method for FNCP production [29].

The CNPs made from ionic liquids were created quickly and in an environmentally friendly manner thanks to microwave assistance. The single-step green preparation approach is quick and efficient; it doesn't require either a surface modification agent or a strong acid solvent, making it ideal for mass manufacturing. Due to its benefits in low-cost production, minimum cytotoxicity, intense fluorescence, and great biocompatibility, CNPs could be an ideal choice for a fluorescent probe to detect [30].

3.4.1.1 Applications for detecting pesticide residues and fruit samples

Pesticides are frequently employed in agricultural fields, but their lingering effects on the environment endanger people, animals, insects, and ecosystems. Pesticides that are overused for insect control, crop yield enhancement, etc., leave behind a sizable residual quantity in the environment. For the monitoring and control of pesticides, numerous durable, trustworthy, and reusable systems utilizing a wide range of composites have been developed. Researchers have found that a variety of properties of carbon nanomaterials, including high porosity, conductivity, and simple electron transfer, can be successfully used to identify food contamination by pesticides. During the following discussions, it emphasized the significance of carbon nanomaterials in the investigation of residual pesticide levels in different food matrices [31].

Monocrotophos is sold as a reddish-brown solid and appears as colorless crystals with a faint ester odor, applied as a quick-acting insecticide with systemic and contact activity against several pests. Monocrotophos is a widely used pesticide be-

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cause of its toxicity to pests, but because it leaves residues in crops, there are negative effects on food quality and human health. An MWCNT-based biosensor was developed for the quick and precise detection of ops in order to address this problem. High sensitivity and narrow detection limits were displayed by this sensor during the evaluation of real fruit samples. Diazinon also comes under the category of Ops, which are harmful and produce negative results when ingested. It was successfully found in fruit samples using a CNT-based biosensor with low detection limits. Therefore, CNTs ensure that food meets the necessary standards for quality, which is vital for food safety and security [31].

For the very first time, full-color CNPs from Eucalyptus twigs were created using a cost-effective, environmentally friendly process called differential washing (DW). LBCNPs had the greatest QY of 10% out of all the fractions, although there were no surface passivation processes taken throughout the synthesis. While the CNPs' size, shape, and zeta potential were satisfactorily and the CNPs' surface clusters were after being described by DLS and SEM, they were XPS and FTIR identified. LBCNPs were used to create a specific fluorescence "turn-off" sensor having a 200 nM threshold for detection of BB in water because of their excellent photo stability. The mechanistic analysis, which included lifetime, temperature-dependent, and UV–visible fluorescence tests, pointing at a mixed squelching result that included dynamic and transient quenching. Then, the 1H NMR study convincingly demonstrated that an H-bonding link that occurred between the particle's COOH molecule and the BB's SO_3 group was what caused the temporary quenching. In order to quickly and affordably detect BB in food specimens, LBCNPs were also used. Due to the LBCNPs' excellent biocompatibility at a variety of suitable doses, they might be utilized in cellular imaging as fluorescent probes without causing any harm [31].

3.4.1.2 Application in food packaging

For active food packaging, an antibacterial nanosheet has been created to replace conventional plastic. It was discovered that CNMS had flexible activity and was less hazardous. Carbon dots were used to create an eco-friendly antimicrobial bacterial nanocellulose (BNC) sheet with UV protection and antibacterial action against L. monocytogenes. The bacterial film was created using CDs that were 500 mg/mL in concentration and 2.8 nm in size. The research investigation found that the manufactured film had both effective antibacterial activity against *Escherichia coli* and acceptable mechanical qualities. Given their versatility, polymers are frequently utilized in food packaging ease of processing, capacity to be recycled, and economic desirability. Unfortunately, no polymer can completely obstruct the gas, and the majority of polymers let the passage of UV light. Many foods, however, require UV protection in addition to gas protection during storage. When exposed to, for instance, UV radiation, several types of milk having the vitamin B2 riboflavin significantly lose vital minerals [32]. It is recommended that various UV-blocking compounds be used in food packaging materials to reduce the chance of polymers

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absorbing UV radiation [33]. UV-absorbing materials, such as CDs, have the potential to alter the nature of light by absorbing specific, recognizable wavelengths. As a result of their significant down-conversion characteristics, CDs' high degree energy loss occurs when light dispersion and reflection quickly transform ultraviolet photon energy into heat.

3.4.1.3 Improving the UV barrier's efficiency in packing film

As a result, it was thought that the hybrid film created from CDs would be especially beneficial as a material for packaging in the food processing industry where goods need to be protected from UV radiation [34]. The UV barrier qualities of the materials used in CD-based food packaging have drawn a lot of attention. Acetic acid bacteria create bacterial nanocellulose (BNC), an organic biopolymer with ribbon-like fibrils. It can adsorb a wide range of materials, has exceptional functional, mechanical, and physicochemical qualities, and is beneficial in the domains of cosmetics, textiles, medicine, food, and water treatment. For active and intelligent food packaging, BNC is also regarded as a supporting biomaterial [35]. Fatemeh et al. developed a better nano paper using BNC. For 14 hours at 30°C, the BNC paper was soaked in a CD solution (530 g/L) to make nano paper with potent antibacterial and UV-blocking characteristics. The addition of CDs to BNC improved the ultimate tensile strength of nano paper while significantly reducing the breaking strain.

CDs have been used as a covering material for fruit and vegetable preservation in a number of experiments due to their high antioxidant activity. Eskalen and others [36] studied banana preservation and looked into the potential antioxidant properties of water-soluble fluorescent CDs made with rosemary leaves as a carbon source. PVA solution and CDs were combined to create the coating solution. Bananas of equal size were treated with PVA solution and PVA-CDs solution, with the untreated banana acting as the control. The number of black spots and patches on the banana peels were used to estimate the degree of oxidation. Untreated bananas turned black on day 19 of the experiment, but PVA-treated bananas were mostly black. Similar approaches were used on bananas by Wang et al. utilizing PVA solution and a CS-CDs/PVA (coffee bean shell-CDs/PVA) mixed solution [37].

3.4.1.4 Application in the food industry as antibacterial and antioxidant agent

CDs have the potential to be employed as an antioxidant and antibacterial agent in food due to their exceptional antioxidant and antibacterial properties, as well as their nontoxicity or low toxicity. Banana-based CDs can effectively stop the growth of *S. aureus*, *Bacillus subtilis*, and *E. coli* [38]. CDs and chitosan solutions can be used to improve the shelf life of soymilk. After 4 days at room temperature, the total bacterial count in soy milk with 8% CDs and 0.16% chitosan was much lower than that of regular soy milk. On the electronic nose, the flavor characteristics of all processed soymilk samples were comparable with those of the control samples. Carbon dots have many uses in the food industry due to their excellent chemical

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stability, water solubility, and ease of manufacture. Numerous studies have been done on the production of carbon dots using Cannabis sativa as a precursor; the carbon dots operate as an antibacterial agent against *E. coli* and *S. aureus*. As a result of their inherent antibacterial properties, CNMs are anticipated to be best suited as food preservatives and packaging materials.

In large-scale applications, toxicology is a crucial parameter for evaluating the potential effects of the CD on the local population and the environment. Fortunately, the majority of recent biological toxicity experiments have demonstrated that CDs have excellent biocompatibility and may be eliminated through normal metabolic pathways without significantly altering pathological processes. In comparison to metal quantum dots, CDs are more physiologically safe for organisms [39].

In order to guarantee that everyone on the planet has access to better health, a healthy diet, and safe food, it is inevitable that the food and food-packaging industries will adopt innovative and cutting-edge technology. The peculiar properties of carbon-based nanomaterials have been the subject of several research studies over the years, and more recent developments in the development of modern procedures for food analysis, food safety, and food packaging are now more clearly visible. Researchers have discovered that current food packaging materials cannot be outperformed by carbon nanoparticles such as carbon dots, carbon nanotubes, and graphene. The CNMs are easy to produce and safe for the environment. Due to their inherent antibacterial qualities, CNMs can be used as food preservatives and packaging materials. Antibacterial nanosheets were developed to replace conventional plastic in active food packaging [39]. Various applications of carbon nanoparticles in the food industries have been illustrated in Fig. 3.3.

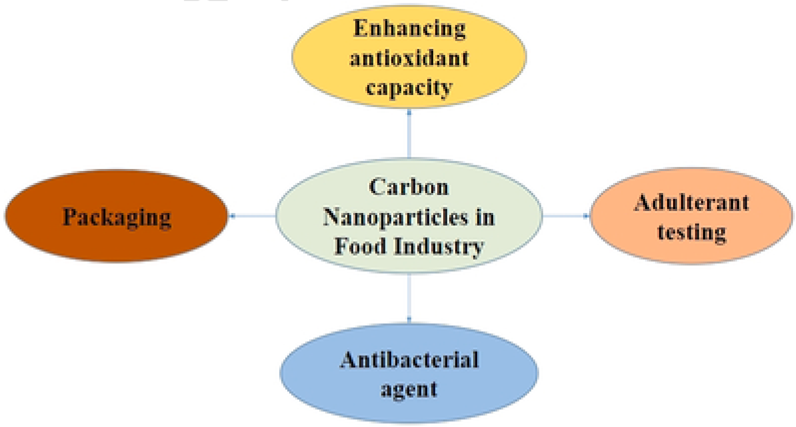

FIGURE 3.3

Nanoparticles in food industry.

3.4.2 Biomedicine

The use of nanomaterials in drug delivery and bioimaging has become a prominent field of research. Even though a variety of materials, such as metallic nanoparticles (Au and Ag), semiconductor quantum dots, and magnetic nanoparticles have been widely used in the delivery of drugs and bioimaging systems, these materials frequently exhibit target-specific action because of their poor biodistribution, low compatibility, and solubility in aqueous media. After extensive research, it has been determined that carbon nanodots belong to an entirely new family of fluorescent nanoparticles [40]. These materials' advantages, such as superior photo stability, water stability, and biocompatibility, make them a strong replacement for previously accessible nanoparticles. According to this theory, fresh techniques have been developed to make green carbon nanodots. CDs have previously been created using watermelon peel, camphor, honey, potatoes, milk, strawberries, oranges, bananas, apples, sugar cane, bamboo leaves, and food scraps. All of these demonstrated how simple the hydrothermal carbonization in aqueous medium process is to use to produce luminous CDs. New quantum-sized carbon-containing fluorescent nanoparticles (CDs) have gained a lot of attention due to their excitation-dependent fluorescent features as they have developed into a significant class of imaging probes and a flexible platform for drug carriers. Doxorubicin (DOX), an anticancer medication, was successfully released into cells under pH control by Zhou et al. using CDs-encapsulated mesoporous silica complex [40]. Sharon's team informed them of the use of CDs made of gum Arabic and sorbitol for the transfer of DOX and ciprofloxacin with regard to target specificity. Additionally, utilizing green tea and CDs made from glycerol, a theranostic medicine for the regulated pharmacokinetics of anticancer medications (quinine sulfate and DOX) was developed. D'Souza et al. employed carrot roots that were successfully included in *B. subtilis* and demonstrated complimentary with MCF-7 cells to produce stunning CDs. These CDs were hydrogen-linked to the anticancer drug Mitomycin and displayed a pH-responsive release property. Targeting milk-derived CDs and doxorubicin in ACC-2 adenoid cancer cells. Doxorubicin conjugation with CDs improved the cancer treatment's efficacy by enhancing the drug's internalization in the nuclei of tumor cells [41].

Some researchers have produced CDs from harmful cyanobacteria that were coupled with DOX and fed to the intended cancer cells for both in-vivo and in-vitro testing. Wang's team produced DOX drug carriers by using bovine serum albumin as a precursor and the solvothermal method to synthesize hollow CDs. The ultrafine size, multifunctional groups, and superior photoluminescence of the fluorescent CDs make them ideal drug delivery vehicles for loading and delivering medications, as demonstrated by the ease with which the lisinopril-loaded CDs were absorbed by the HeLa cells. The results of cellular uptake and cell viability show that the fluorescent CDs are biologically compatible and function as imaging probes for HeLa cells. So the CDs-based lisinopril drug delivery method holds promise for both medication administration and cellular imaging [41].

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A hydrothermal carbon nano dot–based NIR-II emitting nano sensor has been developed and heated it to 190°C for 3 hours after activating it with an 808 nm laser. Between 900 and 1200 nm, the CD emissions showed a QY of up to 0.4%. These NIR fluorescent CDs have been proven to be reliable probes for in vivo imaging of renal excretion. It may also be able to meet the requirements for fluorescent SARS-NIR CoV-2 detection [42]. Solvent extraction combined with the solvothermal method resulted in the development of the distinctive carbon-rich quantum dots formed from biological materials (also known as "biomass quantum dots, BQDs") with dual-emission and single-excitation properties. This carbon nanocomposite of CBQDCu based on spinach showed potential for near-infrared fluorescence imaging when copper ions were added [42].

Doxorubicin conjugated due to their excellent fluorescence properties and good biocompatibility, drinkable source-derived CDs (BCD-DOX) are a potentially safe material for image-guided drug delivery and bioimaging in the treatment of cancer. The results of the cytotoxicity research demonstrated that there was no obvious reduction in cell viability at concentrations as high as 12.5 mg/mL over 48 hours [42]. The antibiotic Ciprofloxacin was delivered to bacterial cells using gum Arabic CDs. Gram-positive (*Pseudomonas aeruginosa*) and Gram-negative (*E. coli*) bacteria were both used by the researchers. *S. aureus* and *B. subtilis* were used to test the antibacterial activity of the drug-loaded CDs, and the naked CDs had very little effect on these microbes. The CDs linked to the drugs were less effective against Gram-negative bacteria than they were against Gram-positive bacteria [43].

Some researchers have employed a "green," fast, eco-friendly, waste-reused method to make water-soluble and bright C-Dots from eggshell membrane (ESM) ashes. These ESM-derived C-Dots, which were very expensive to make, displayed astounding fluorescence properties and had a lot of application potential in biotechnology and sample detection [44]. The calcium alginate (CA) film that Sarkar et al. developed for a study on pH-responsive drug delivery was coated with aloe vera leaf gel CDs. To create a brand-new hybrid nanoparticle, the CD-coated CA films were combined with cyclodextrin that was loaded with vancomycin. These hybrid nanoparticles demonstrated increased medication loading efficiency (96%) and prolonged drug release at a low pH [45].

Green CDs have the potential, according to the study, because of their unique properties, which include outstanding cargo loading efficiency, photo stability, enough quantum yield, and sustained fluorescence. It has been shown that "naked" green CDs can be found in specific places such organelles, cytoplasm, and cancer cells. Even if the majority of CDs' surface functionalization has probably been correlated with their intracellular and nuclear localization, this is the case. Green CDs have shown tremendous potential for self-targeted imaging as well as a format for targeting tumor cells and cellular organelles, thus it is interesting to continue developing them in this way. They are suitable for biological applications because, when combined with therapeutic or targeted medicines, they still exhibit fluorescence. In vivo fluorescent imaging has issues with poor tissue penetration and auto fluorescence background [46].

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Bioimaging CNT-based imaging probes have also drawn a lot of interest. The quasi-one-dimensional (1D) semiconducting SWNTs may produce fluorescence in the near-infrared (NIR) regions, including the traditional NIR-I area (700–900 nm) and the recently revealed NIR-II region, thanks to their very tiny band gap of about 1 eV (1100–1400 nm). SWNTs have a powerful resonance. Raman scattering has a very broad scattering cross section, making it possible to create excellent Raman probes for biological imaging and sensing [47].

An altered glassy carbon electrode (GCE) with immobilized hemoglobin has been combined with a multiwalled carbon nanotube/zinc oxide (MWCNT/ZnO) mixture to create an incredibly sensitive and accurate amperometric hydrogen peroxide sensor. Biosensor for (H_2O_2). The developed biosensor has a low detection limit of 0.02 M, good sensitivity, a large linear range, and an incredibly fast reaction time (>2 seconds) to H_2O_2. Along with excellent conductivity, MWCNT's straightforward electron mobility, and ZnO's great biocompatibility, the constructed biosensor also stood out for its high selectivity, appropriate stability, respectable reproducibility, and repeatability. A representation of the typical chemical reaction structure of graphene nanodots driven by the NIR, which are employed for optical imaging and therapy among other things, is shown by graphene nanodots [CGQDS] with carboxyl functionalization and an excitation wavelength of 655 nm. These scientists conducted a number of experiments, including one in which they visualized MDA-MB231 in breast cancer–bearing mice both in vivo and in vitro. The experiment's findings demonstrated that graphene nanodots might help visualize tumor tissue in mice and could be used as a tool for noninvasive imaging of cancer in deep tissue and organs. Another work employed imaging to develop a serum albumin (BSA)-cis-aconitylpheophorbide-a (c-PheoA) functionalized GO nanocomplex using the cancer cell line and the MCF-7 cell line (human breast adenocarcinoma) [48].

A straightforward process has been created for the mass production of water-soluble green carbon nanodots (Gdots), which may be made from a number of sources and come from massive volumes of food waste. The G-dots' high level of water solubility is a result of the abundance of oxygen-containing functional groups that surround their surface. These G-dots are excellent sensors for in vitro bioimaging because of their low cytotoxicity and high photo stability. The outcomes clearly showed that over the course of 24 hours, Gdots (at concentrations up to 2 mg/mL) had no negative effects on the cell lines [48]. The search for microscopic biomarkers with stable fluorescence served as the impetus for research on fluorescent semiconductor nanocrystals. The use of quantum dots (QDs) was one of the alternatives examined. They provide organic dyes and proteins with much improved optical properties compared with a high photobleaching limit, broad excitation, and narrow emission spectra, as well as very high quantum efficiency. However, there are two issues with QDs: They are moderately cytotoxic, lack fluorescent properties, and show nonstable fluorescence rather than a nonlinear blinking feature. As a result, interest is currently concentrated on carbon-based nanomaterials, especially nanodiamonds. When applied to cells, nanodiamonds did not appear to produce reactive

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oxygen species (ROS) or be harmful to the majority of cell types, as suggested by Schrand and colleagues. Nanodiamonds have a better possibility of becoming biomarkers than QDs since they seem to be biocompatible, a critical trait of biomarkers. Nanodiamonds' carbon structure can be easily functionalized by binding biological molecules like proteins in addition to its optical and biocompatible properties. As a result, there is a greater chance of producing bio conjugates, which could aid in the development of cellular and molecular imaging studies. As intracellular markers, antibodies may be linked to green fluorescent nanodiamonds, which has been demonstrated to be possible. The results show that cellular auto fluorescence and nano diamond–mediated fluorescence may be separated based on fluorescence intensity and photobleaching. The nano diamond immunoconjugates can be efficiently transported intracellularly using a number of transfection techniques, including dendrimers and protamine. With the correct antibody, nano diamond conjugates can be directed to intracellular components such as the mitochondria. Nanodiamonds are a promising substance for testing in living intracellular cells due to their high photobleaching resistance and purported lack of cytotoxicity. According to these results, nanodiamonds might someday be used as biological biomarkers for human cells. The use of nanoparticles offers a potential substitute for avoiding drug efflux routes. Nanoparticle pharmaceutical delivery can increase intracellular drug concentration and therapeutic effectiveness by entering the cell through endocytosis. Due to chemical modifications, several important cancer therapies, including water-insoluble medications, may now be delivered by NDs. Additionally, NDs have been used to optimize the drug release qualities in a variety of implanted devices for localized tumor therapy.

For the advantage of the biological analyzer, a carbon nanotube biosensor includes specific bio-inspired receptor links that are similar to the DNA of bacteria or viruses and proteins produced by infected live organisms [49]. Due to their exceptional enzyme resistance and highly smooth adsorptive qualities on the surface of nano carbon, small proteins are employed for gene release. It is excellent for cancer drug delivery systems since it can self-assemble and move between cells to migrate toward nucleic acids (DNA and RNA). One material that might have a better affinity for the improved biosensor is nano carbon tubes. The influenza virus has been recognized by a nano carbon-based biosensor that has been modified with glycans [50]. Due to their extraordinary capacity to quench radicals, fullerenes have generated a lot of interest as possible medicinal antioxidants. Single electrons from radicals are quickly incorporated into their extended conjugated form. Aqueous solutions of C60 had no detrimental effects on Chinese-hamster V79 cells [51]. However, it was shown in another investigation that the cytotoxicity of C60 in aqueous solution was brought on by the generation of singlet oxygen. The study's most significant finding is that cytotoxicity is sensitive to the number of functional addends attached to the cage, and that higher hexahedral functionalization can reduce cytotoxic effects by almost seven orders of magnitude. Through a one-step, additive-free hydrothermal treatment of grape juice, fluorescent carbon nanoparticles (CPs) production has been made simpler, more affordable, and environmentally friendly.

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The human Hela cells were incubated at 37°C in a humid incubator with 100 g/mL penicillin/streptomycin, 10% fetal bovine serum, and DMEM. The CPs suspension was applied to a chamber slide well at a final concentration of 20 g/mL. After a day of incubation, the cells underwent three phosphate-buffered saline rinses. The long-pass filter in use had a wavelength of 530 nm, and 488 nm was the excitation wavelength used to capture the fluorescence images. The results show that grape juice-derived CPs can work well as a bioimaging probe [52].

Wu et al. created a novel one-step solvothermal technique to produce fluorescent CNPs using triple-distilled water as the carbon source, glycol as the solvent, and L-ascorbic acid as the carbon source. When subjected to UV light, the created CNPs were found to be water-soluble, monodispersed, and capable of emitting persistent green fluorescence over a wide excitation wavelength range. Within a certain range, there was a significant linear relationship between the fluorescence intensity and the solution's pH. It was found that the created CNPs might be used as a tool for biological analytical applications [53]. Muesli was hydrothermally treated to produce extremely photo luminescent and 37.40% quantum yield carbon nanoparticles without the need of any surface passivation or oxidizing chemicals. Due to their potent fluorescence, superior photo stability, low toxicity, and other properties, the carbon nanoparticles that have been produced have proven to be effective biocompatible probes for bioimaging [54].

A simple method for producing photo luminescent carbon nanoparticles (CNPs) from waste plastic bags (WPBs) uses hydrothermal treatment in low-concentration H_2O_2 solutions (5.0 wt.%). Risky regulators, difficult synthetic conditions, and time-consuming steps weren't necessary for this method. The size of the CNPs can be precisely controlled by simply raising the H_2O_2 concentration; higher H_2O_2 concentrations lead to smaller CNP particle sizes. CNPs are fascinating candidates for cellular imaging because of their strong photoluminescence, superior optical stability, low cytotoxicity, and exceptional water dispersibility. This simple technique satisfies the intriguing "waste-to-treasure" conversion and offers a creative plan for the effective reuse of WPBs [55]. Various applications of carbon nanoparticles in the healthcare sectors have been describes in Fig. 3.4.

3.4.3 Agriculture

As a result of nanotechnology's potential to provide new tools for the molecular control of illnesses, quick disease diagnostics, enhancing plant nutrient absorption, etc., the food and agriculture industries may experience a total makeover. The agriculture business will be assisted in combating viruses and other crop problems by smart sensors and smart delivery systems. Nanostructured catalysts will soon improve the efficacy of fertilizers and herbicides, enabling the use of lesser amounts [56,57]. Both organic and synthetic fertilizers contain chemical components that encourage plant development and productivity. The majority of contemporary fertilizers are composed mostly of the three macronutrients nitrogen, potassium, and phosphorus. The fundamental goal of fertilizer is to improve plant development.

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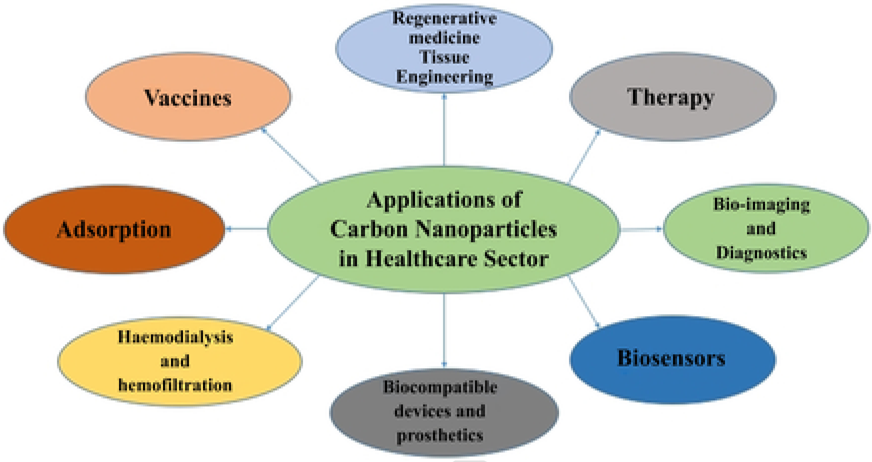

FIGURE 3.4

Applications of carbon nanoparticles in the healthcare sector.

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One of two methods is used to achieve this goal: historically, nutrient-rich additives are given to plants. Altering the soil's water retention and aeration could also increase the usefulness of the soil [58].

It has been found that the activation of water channel and cell wall expansion proteins by CNMs at low concentrations is responsible for the improvement of water intake, seed germination, seedling growth, and nutrient absorption. High concentrations of CNMs increased the production of free radicals and certain antioxidant enzymes, but this also resulted in oxidative stress events and cell damage. Additionally, CNMs improved the adsorption of beneficial medicinal (carotenoids) molecules in a dose-dependent manner. The synthesis of secondary metabolites may be controlled by CNMs altering the genes linked to those pathways, according to research [59].

Chloroplast photosynthesis is the method used by plants to transform solar energy into chemical energy. Chloroplasts, which can only use light in the visible spectral range (400–700 nm), mostly in the blue and red, use less than 10% of sunshine. Plant photosynthesis does not use UV or IR light sources. In order to maximize the utilization of solar energy and broaden the light spectrum for plant photosynthesis, high-performance light conversion materials with blue and red broadband emissions may be feasible. The use of various light-trapping nanomaterials to transform weakly absorbed UV light into well-absorbed visible light to speed up plant photosynthesis has boosted the efficiency of the light utilized by chloroplasts. Due to their consistent emission and diverse photoluminescence spectrum, CNMs are commonly used as down-conversion nanomaterials (DCNMs) to transform ultraviolet (UV) light into photosynthetically active radiation [57].

Nanofertilizers are nanomaterials that give plants a particular nutrient or a combination of two or more nutrients, resulting in an increase in growth and the yield of the crop. All those nanomaterials that enhance conventional fertilizers without directly feeding crops nutrients are also referred to as nanofertilizers [60]. Future agricultural productivity may surely be significantly impacted by carbon nanoparticles, particularly if they increase food production and enhance agricultural sustainability. However, depending on the plant species, CNM type, and dosages, these effects may differ. Because the majority of the current research on CNMs in agriculture is done in labs, considerable field application data must be obtained before CNMs can be used widely in agriculture in the future. Scientists recently created monitoring techniques based on nanosensors to improve plant health, including parasite connections and disease identification and control. The use of nanosensors in molecular biology applications, such as the detection of plant illnesses, the prevention of soil and water pollution, the management of harvested crops and flowers, the reclamation of contaminated soil, etc. Nano biosensors can be used to detect various fertilizers and plant diseases using a system for regulating plant nutrients, reducing nutrient loss, and increasing crop yields [61]. In this context, a CNT-based digital sensor may be used in remote sensing systems for plant diseases to identify dangerous gases that can be consumed by insects or plants in real time. An acetylcholinesterase biosensor for the detection of organophosphate herbicides was created through the fabrication of multiwalled carbon nanotubes onto liposome bioreactors. SWCNT-based hybrid nanosensors for gases, including ammonia, nitrogen oxide, hydrogen sulfide, sulfur dioxide, and volatile organics, may be used to measure agroecosystem contaminants, assess the effects on living things or health, and improve agricultural output. SWCNT-based hybrid nanosensors for gases, including nitrogen oxide, ammonia, sulfur dioxide, hydrogen sulfide, and volatile organics. This may be used to evaluate agroecosystem pollutants and increase agricultural productivity [61]. The utilization of a variety of readily available carbon nanomaterials, such as graphene oxide, allows for the mass production of encapsulated fertilizers with a controlled release strategy and can be sold for less money [62]. Carbon nanotubes can carry both macro- and micro-elements, and they can even be utilized as slow-release fertilizers to cut back on the excessive amounts that are generally used [63]. Because of its antifungal qualities, carbon nanoparticles are an exciting material to utilize in the creation of various nano insecticides. CNTs greatly reduced the mycelium's ability to form spores when the effects of industrial MWCNTs on the entomopathogenic *Paecilomyces fumosoroseus* fungal conidia were investigated [64,65]. In the agricultural sector, pesticide residues in the soil are a major issue. Researchers have looked into the possibility of employing carbon dots to detect pesticides in various food and agricultural products [66,67]. The ability of CNT-based optical and electrochemical sensors to detect extremely low amounts of pesticide residues, particularly on the surface of the plant, may be of considerable use to the food sector [68,69]. Various applications of nanoparticles in the field of agriculture have been illustrated in Fig. 3.5 (Table 3.1).

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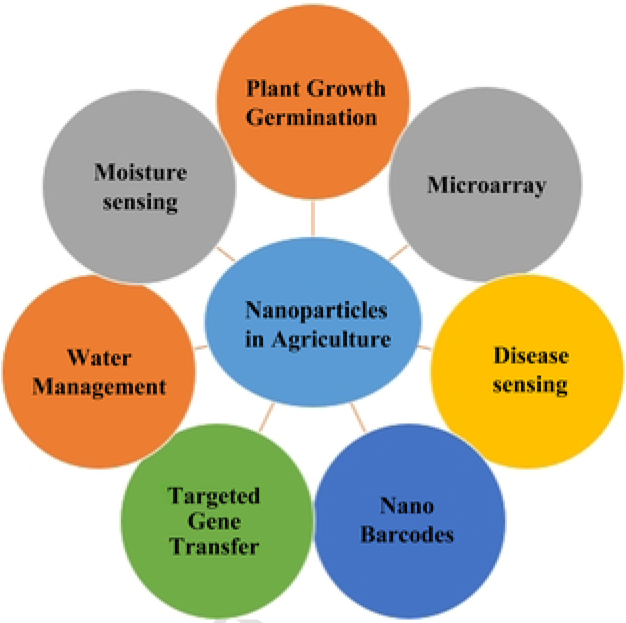

FIGURE 3.5
Applications of nanoparticles in agriculture.

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3.5 Conclusion

In recent years, there has been a significant increase in interest in and focus on the field of nanotechnology and nanoparticles. Although there are several methods for creating these nanoparticles, scientists are worried about the harm that they can do to the environment if they are created through traditional methods. Consequently, there has been a lot of interest recently in a new field called green production of nanoparticles. This chapter largely concentrated on the various methods for creating green carbon nanoparticles and their applications in significant industrial domains. This chapter gives a brief overview of the uses of environmentally friendly technologies to create carbon nanoparticles in food, biomedicine, and agriculture.

TABLE 3.1 Carbon nanoparticles, their applications in various domains.

S.L No	Types of carbon nanomaterial	Domain of application	Key findings	References
1	Carbon QD Carbon nanotubes Nanowires	Food	Detection of contaminants in food with nano based sensors Early detection of egg-borne pathogen	[70,71]
2	Carbon QD Carbon nanotubes	Food	Vegetarian meat produced in large quantities in laboratories, preserving the flavor and texture of genuine meat without any of the risk	[72]
3	Carbon nanotubes	Food	Customized eggs with desired antibodies, more significant vitamins, and low cholesterol	[73]
4	Carbon nanotubes	Food	Nanomaterials with high permeability for packaging food to shield it from UV rays Giving the food more vigor to keep it protected from the environment, extending its shelf life	[74]
5	Zeolites and nanoclays	Agriculture	Zeolites and nanoclays are used to retain water or liquid agrochemicals in the soil or to release them gradually to the vegetation.	[75]
6	Nanomaterials and nanoclays CNT filters	Agriculture	Filters are employed in water purification and pollutant remediation to remove contaminants from the environment.	[76]

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S.L No	Types of carbon nanomaterial	Domain of application	Key findings	References
7	Nanomaterial-based gene-delivery systems Liposomes nanomaterial	Biomedicine	Using nanomaterials to deliver deoxyribonucleic acid in plant breeding Ribonucleic acid, which is triggered by pathogens, is used to plant cells for genetic transformation or to cause defense responses.	[77]
8	QDS nanoparticles	Biomedicine	Detection of neurodegenerative disease-related compounds	[78]
9	Nanomedicine and "nanorobots"	Biomedicine	detection of pathogenic microbes and viruses, such as the human immunodeficiency virus, fungus, and morbific bacteria.	[79]
12	Liposomes, compound nanoparticles, nanocrystals, and specialty compounds such as dendrimers, fullerenes, carbon nanotubes and inorganic nanowires	Biomedicine	Therapeutic drug delivery systems.	[80]
13	Carbon nanotubes	Biomedicine	Applied in medical implants and scaffolds for grafts.	[81]
14	Quantum dots	Biomedicine	Used for experimental medical imaging applications bioimaging applications.	[82]
15	Dendrimers	Biomedicine	Applied in regenerative medicine	[83]

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CHAPTER

Role of different types of carbon nanotubes in food sciences and food sensing applications

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Balaji Doolam[1], Divyamshu Surabhi[1], Chandan Kumar Gautam[2], Rajasri Yadavalli[1], Naru Rakesh Reddy[1], Aishwarya Kulkarni[1], Karthikeya S.V. Gottimukkala[3], Sanjeeb Kumar Mandal[1], Bishwambhar Mishra[1,*]

[1]Department of Biotechnology, Chaitanya Bharathi Institute of Technology, Hyderabad, Telangana, India; [2]Department of Biology, University of Miami, Coral Gables, FL, United States; [3]Department of Laboratory Medicine and Pathology, University of Washington, Seattle, WA, United States;

[*]Phone: 040-24193276; Email Id: bishwambhar_biotech@cbit.ac.in

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7.1 Introduction

"Nutrition isn't just about eating, it's about learning to live." beautifully written by Patricia Compton, illustrates the prime necessity to fully understand the food product we consume. To understand the properties associated with the complex food molecules, food science is applied; whose scope grays the line between agricultural and nutritional science(s) and focuses on the development of food safety, food processing, food packaging, how molecules such as carbohydrates, lipids, proteins, and water interact with each other under storage conditions. Additionally, the birth of food technology has given numerous opportunities to improve the fields explored by food science and to understand the concentrations of various components present in various foods. This is where the exponential advancement of nanotechnology provides limitless potential toward the improvement of food sciences, food sensing biosensors, and food properties such as texture, taste, and nutritional value [1–3].

One of the 21st century's most promising technologies is nanotechnology (NT). NT is defined as "a science, engineering, and technology conducted at the nanoscale (1–100 nm), where a unique phenomenon enables novel applications in a wide range of fields, ranging from chemistry, physics and biology, to medicine, engineering and electronics" according to National Nanotechnology Initiative (NNI),

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USA. In short, any technology that works at the nanoscale is called NT. Among the varied applications of such technology, the brightest gem of all is its role in the agricultural and food sector. Due to the increased surface-to-volume ratio and unique biological, chemical, and physical properties, nanomaterials have gained much interest in agro-food, medicine sectors, and other industries compared with macro-sized particles [3,4].

Nanomaterials such as CNT play a significant role in the food industry. CNTs are tube-like structures that are composed of carbon and have a diameter of nanometers. CNTs are one-dimensional nanostructured carbon materials, formed when graphene sheets are rolled up to form a cylindrical tube-like structure. Laboratory investigations have found nanometer-wide hexagonal lattices, which are light, biocompatible, conductive, and had the strongest tensile strength. In a wide range of fields starting from academia to industry, CNTs have attracted a lot of researchers as they are promising materials in NT in the future [5–7]. Recent breakthroughs in the use of CNTs in food sensing and applications have led to the development of several innovative solutions. These include the rapid detection of various analytes [8–12], food-borne pathogens, monitoring of food contaminants [13–15]; to enforce food safety and packaging applications [16–18]. Additionally, CNTs are being used for the microextraction of specific particles, such as heavy metals in food samples and phthalate acid esters in beverages and alcoholic samples, to enhance food safety and quality control [19–21].

7.1.1 History

Carbon was first discovered in the form of graphene in 1779, and then diamond was discovered 10 years later. The year 1985 saw the discovery of fullerenes by Kroto, Smalley, and Curl. CNTs were discovered in 1991, a few years later, by Sumino Iijima. Although CNTs had been developed and investigated in a variety of settings before to 1991, Iijima's report is particularly significant since it made the scientific community aware of CNTs. A Japanese physicist named Sumio Iijima carried out an experiment in which he put an electric current across two graphite rods, causing a spark to form between them and a puff of carbon gas to be released, vaporizing the anode rod's tip. The carbon-rich air landed on the chamber walls, forming a thin layer of black soot. It was discovered that the unusual substance that had grown was a tiny, single-layer carbon straw known as a multiwalled carbon nanotube (MWCNT). The initial MWCNTs are always closed at both ends and have outside diameters between 3 and 30 nm. By scanning a few MWCNTs in 1993 that were thinner than most MWCNTs, a new class of CNTs with a single layer was found. These were known as Single-walled Carbon Nanotubes (SWCNTs), which were curved rather than straight and had a diameter in the range of 1–2 nm [6,22–24].

This chapter describes the distinct types of CNTs and their properties. CNTs have emerged as a crucial element in food science and sensing technology, contributing significantly to food preservation and the measurement of analyte concen-

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trations in food samples. Their unique properties make them ideal for these applications. Additionally, the article provides an overview of the current state and future possibilities of CNTs in the field.

7.2 Classification of carbon nanotubes and their properties

Carbon allotropes are different forms of carbon resulting from the arrangement of carbon atoms. Some common types of carbon allotropes include Graphene, Diamond, Nanotubes, and Fullerenes. One specific type of carbon allotrope is called CNT, which has a nanostructure with an incredibly high length-to-diameter ratio, sometimes exceeding 1,000,000. These nanotubes consist of concentric carbon shells with an adjacent separation of 0.34 nm. Graphene, a component of CNTs, forms a honeycomb-like network of carbon shells. This unique structure enables CNTs to possess high Young's modulus, exceptional electrical and mechanical properties, and impressive tensile strength. CNTs can be further divided into SWCNTs and MWCNTs based on their structure and characteristics. Each type of CNT exhibits distinct features due to their structural differences [5,25–27].

7.2.1 Single-walled carbon nanotubes and their properties (SWCNT)

SWCNTs, commonly known as graphene nanotubes, are allotropes of sp^{2-}hybridized carbon. A sheet of graphene that has been rolled into a tubular form can be used to represent the structure of SWCNTs as illustrated in Fig. 7.1. A buckyball or fullerene structure may be used to cap the ends of these tubular constructions. Depending on the chirality of the nanotube, several characteristics, such as orientation and the diameter to which the graphene sheet must be rolled, alter. The characteristics of different SWCNTs are determined by the nanotube's chirality [6,25,28].

7.2.1.1 Properties of SWCNTs

SWCNTs have several unique properties across different domains. SWCNTs are 100 times stronger than steel in terms of mechanical qualities, and they weigh only $1/16^{th}$ its weight [29,30]. For electrical properties, SWCNTs have a high current-

FIGURE 7.1

Rolling of a graphene sheet to form SWCNT.

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carrying capacity, exceeding that of copper and gold, and semiconducting species have higher mobility than silicon [29–31]. In terms of optical properties, SWCNTs have unique optical absorption and fluorescence properties depending on their chirality, and coatings made with SWCNTs are transparent in the visible region, making them useful in displays and solar cells [29,30]. SWCNTs have high thermal conductivity, comparable with that of diamond or in-plane graphite that is thought to be the greatest thermal conductivity yet seen in a material at moderate temperatures [29,30].

7.2.2 Multiwalled carbon nanotubes and their properties (MWCNT)

When numerous layers of graphene are concentrically rolled into a cylindrical structure as demonstrated in Fig. 7.2, to create MWCNTs, their structure can be compared with the concentric arrangement of SWCNTs [5]. The structures of SWCNTs and MWCNTs are quite similar as sp^2-hybridized six carbon rings as in graphene forming a tubular structure (SWCNTs). MWCNTs are a series of these cylindrical structures that can be viewed as a series of SWCNTs concentrically arranged one after the other. The MWCNTs' diameter may be as high as 30 nm when compared with SWCNTs, which have 0–2 nm diameters [25,28].

7.2.2.1 Properties of MWCNTs

MWCNTs possess diverse properties that make them valuable in various applications. When incorporated into composites, MWCNTs demonstrate high conductivity; however, it is crucial to remember that just the outer wall of the nanotubes is responsible for this conductivity. Morphologically, MWCNTs have a high aspect ratio, with diameter lengths significantly larger than their width. Their performance is influenced by factors such as aspect ratio, straightness, degree of entanglement, and the presence of flaws in the tubes. In terms of physical properties, individual MWCNTs exhibit remarkable tensile strength, which can be further enhanced when they

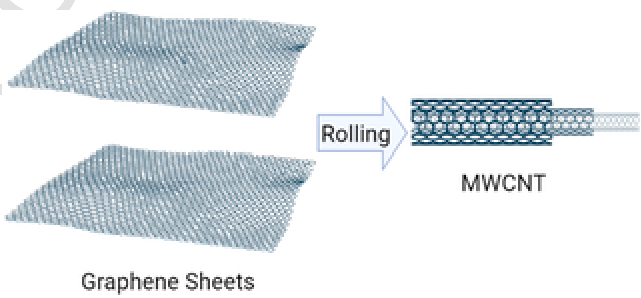

FIGURE 7.2

Rolling of graphene sheets to form MWCNT.

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are included in thermoplastic or thermoset compounds. Moreover, MWCNTs demonstrate thermal stability up to temperatures exceeding 600°C, although this depends on the level of imperfections and purity. However, it is worth noting that any remaining catalyst in the product can catalyze breakdown at high temperatures. Chemically, MWCNTs, akin to fullerenes and graphite, possess high stability due to their composition of sp^2-hybridized carbon. Nevertheless, it is possible to functionalize nanotubes to elevate their strength and dispersibility in composite materials, expanding their potential for tailored applications [6,32]. The comparisons between SWCNTs and MWCNTs are displayed in Table 7.1 [33] and based on properties are discussed in Table 7.2 [30].

TABLE 7.1 Comparison between SWCNTs and MWCNTs.

SWCNTs	MWCNTs
1. There is only one layer of graphene.	1. There are several layers of graphene.
2. For SWCNT synthesis, a catalyst is required.	2. It does not require a catalyst for MWCNTs synthesis.
3. Large-scale synthesis is difficult.	3. Large-scale synthesis is easy.
4. In the functionalization process, defect probability is high.	4. In the functionalization process, defect probability is low.
5. Purity is low.	5. Purity is high.
6. It has a simple structure.	6. It has a complex structure.
7. Easy to twist.	7. Cannot be twisted.
8. Less accumulation occurs within the body.	8. High accumulation occurs within the body.

TABLE 7.2 Comparison of SWCNTs and MWCNTS based on their properties.

S.L No	Parameters	SWCNTs	MWCNTs
1	Diameter	1–2 nm	7–100 nm
2	Length	Up to 1 mm	Up to 1 mm
3	Aspect ratio	Up to 10,000	50–4000
4	Tensile strength	50–100 GPa	10–50 GPa
5	Elastic modulus	50–100 GPa	–1000 GPa

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7.3 Role of carbon nanotubes in food science

7.3.1 Role of CNTs in food packaging and preservation

The ability to transport and preserve food for an extended period is made easier by proper packaging, which has become a standard procedure for extending the shelf life of food. Food can be packed using containers made of glass, plastic, metal, and paper. However, to reduce the environmental contamination caused by petroleum-derived components (plastics), which are widely utilized to package and preserve food, there has been a great focus on using NT to help preserve food and at the same time reduce the pollution produced by the food packaging industry. CNTs have a significant presence in the food sector because of their small size and unique physiochemical characteristics [34–36].

Recent advances in NT have demonstrated that CNTs possess outstanding mechanical, thermal, and electrical qualities that support the strengthening of polymers. The ability of CNTs to strengthen polymers, particularly biopolymers, can aid in the creation of novel uses for CNTs in food packaging. Additionally, CNTs can be used as filler for nanocomposite materials due to their high tensile strength. Due to their role in developing biodegradable polymers for the packaging sector and their contribution to increasing mechanical and barrier qualities, CNTs are essential materials [34,35,37].

Yu et al. [38] produced bionanocomposites by reinforcing 3-hydroxybutyrate and 3-hydroxyvalerate (Polyhydroxybutyrate-*co*-valerate—PHBV) with MWCNTs. They used the solution casting technique and found that the resulting PHBV-g-MWCNTs were evenly distributed throughout the PHBV matrix, leading to improvements in thermal stability and various properties. Compared with clean PHBV, PHBV-g-MWCNTs exhibited an 88% increase in tensile strength, a 172% increase in Young's modulus, and a maximum decomposition coefficient of greater than 23°C [38]. In their study, Kang et al. [17] described the relationship between SWCNTs and *Escherichia coli 12*. The study demonstrated that the plasma membrane damage caused by the SWCNTs caused the *E. coli 12* cells to lose their cellular integrity. The damage produced by the formation of SWNCT aggregates on incubation with cells resulted in the loss of cellular content by the cells. This characteristic of SWCNT supports the notion that CNTs have antimicrobial action. CNTs' antimicrobial properties aid in the packaging and preservation of food [17]. In a study on "the effect of nanocomposite packaging carbon nanotube base on organoleptic and fungal growth of Mazafati brand dates" conducted by Asgari et al. [39], low-density polyethene films incorporating nanocomposite CNTs were produced by solution casting from boiling xylene. These films contained the Mazarati dates in sterile, ambient settings. Microbiological analysis proved that the antibacterial activity increased with the CNT content. The uniform distribution and lack of agglomeration of CNTs have led to an increase in antimicrobial effect. It was concluded that nanofilm decreases fungal growth [39]. In 2013, Dias et al., described

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the creation of CNT with allyl isothiocyanate-based antimicrobial packaging. These films developed have shown antimicrobial activity, decreased impact on the color of food, and helped in controlling oxidation. The most effective combination was concluded to be more than 28% allyl isothiocyanate concentration incorporated with CNT higher than 0.02% concentration. The films created could extend food's shelf life by up to 40 days [18].

Mohammad et al. [16] provided an explanation for the microbial decrease brought about by CNTs against *E. coli*, and *Staphylococcus aureus*. This study revealed significant antibacterial efficacy against *Staphylococcus* and *E. coli*. MW-CNT and SWCNT-coated TiO_2/Ag nanostructures were created using the situ sol–gel method. It was observed that the MWCNTs-TiO_2/Ag were less hazardous than the SWCNTs-TiO_2/Ag. Nanocomposites prepared were also described to have less toxicity than pure TiO_2 [16]. CNTs and their derived composites have antimicrobial activities and can be used in food packaging, but migration and bioaccumulation of nanoparticles can cause safety and health hazards [28,40]. Therefore, it may be said that CNTs are crucial for food preservation and packaging. The role of CNTs in food packaging and preservation has been summarized in Fig. 7.3.

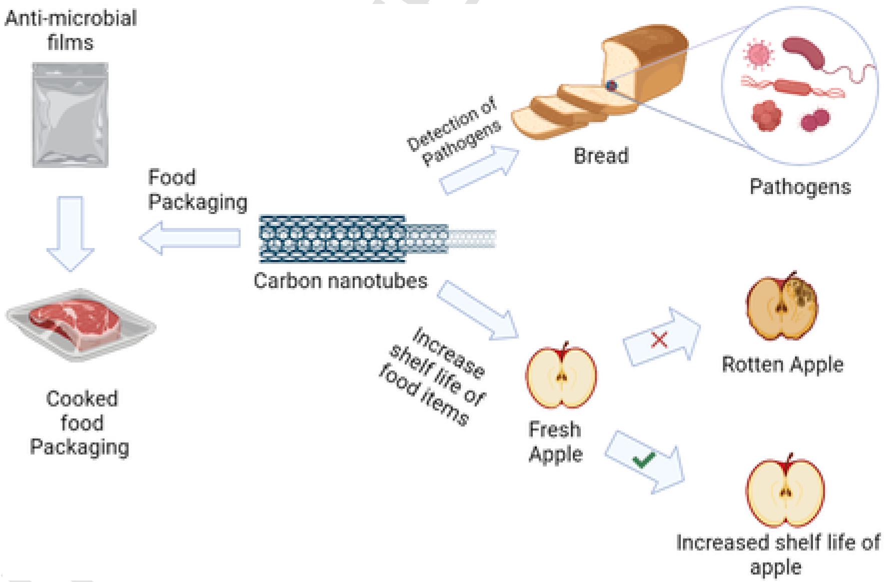

FIGURE 7.3

Role of CNTs in food packaging and preservation.

7.3.2 Role of CNTs in removing heavy metals from food samples

Since the dawn of the industrial revolution, the world has been continuously exploited for the treasures it holds. But just as all that glitters is not gold, the exploitation process has led to the contamination of food on various levels. The industrialization of societies throughout the world has caused a severe environmental crisis. One of the major pollutants and ubiquitous component of the environment are heavy metals (HMs). The mining and processing of metal ores significantly contaminate the environment with HMs. Although these metals naturally occur in the earth's crust human activities such as industrialization and urbanization are leading to the introduction of HMs into the biosphere [41,42].

HMs are metals with a unit weight exceeding 5 g/cm^3, and they are often found scattered within rock formations. They include transition metals, certain metalloids, lanthanides, and actinides. Examples of HMs are Mercury, Lead, Chromium, Cadmium, Arsenic, Manganese, Gallium, Cobalt, etc. These metals are known to be toxic and can lead to various diseases and health issues, including poisoning and cancer. While trace amounts of these metals are necessary for organisms, exceeding certain thresholds can make them contaminants and pose significant health risks [43,44]. The migration of HMs from industrial effluents, agricultural wastes, and various processes is causing environmental damage and pollution of soil, water, and air. These metals accumulate in the food chain, leading to harmful effects on humans, plants, and other organisms. Exposure to HMs can result in serious diseases such as cancer, kidney dysfunction, and organ damage, even at lower levels of toxicity. Lead, for example, can cause short-term symptoms such as headaches and nervous system irritation, while long-term exposure may lead to memory loss and decreased reflexes. Overall, the discharge of HMs into the environment poses significant health risks and has detrimental impacts on ecosystems [26,43,45].

Detecting HMs in food, water, and other items is crucial to ensure they are free from toxins. Various methods are employed in the food industry for detection, including smartphone-based techniques, electrochemical Apta sensors, surface-enhanced Raman spectroscopy, and laser-induced breakdown spectroscopy. However, the challenge of low extraction efficiency persists in these methods, and each approach may have limitations in specific circumstances [45–47]. To address these issues, research groups are exploring the application of CNTs to enhance the efficiency of extracting HMs from food samples. The unique properties of CNTs are being harnessed to improve the detection and removal of HMs, offering potential solutions to enhance food safety [41,42].

Nanoparticles, specifically CNTs, play a crucial role in addressing environmental contamination, particularly in the removal of dangerous contaminants such as HMs. CNTs possess remarkable chemical, electrical, mechanical, and optical properties, making them a promising material in NT. In the realm of adsorbents, CNTs stand out for their ability to rapidly absorb and eliminate harmful contaminants from aqueous sources. By combining CNTs with activated carbon, nanoparticles,

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and nanocomposites, the effectiveness and potential of the adsorbent are further enhanced. The extensive surface area of CNTs, along with their small size and versatile functionalization, contributes to their superior sorption capabilities. Moreover, their chemical modifiability and recyclability make them highly promising for the removal of HMs [19,26,47,48]. The techniques involved in the extraction of HMs in CNTs are quite appealing. The advantages of solid-phase extraction (SPE) material include its high strength, broad surface area, thermal stability, and capacity for proton–proton (p-p) interactions. Metals have a higher binding capacity and selectivity when attaching to either as-grown CNT or functionalized CNT [19,41,48].

MWCNTs can improve the efficiency of extraction processes due to their extreme stability. Therefore, they can be used as solid-phase extractors to extract HMs such as Cu (II), Cd (II), Pb (II), Zn (II), Ni (II), and Co (II) ions as ammonium pyrrolidine dithiocarbonate (APDC) chelates. Additionally, the extraction properties of MWCNTs can be further improved by combining them with certain compounds. The following are some of the combinations that are being practiced currently [19,48]. The use of MWCNT impregnated with 2-(2-benzothiazole) orcinol as an SPE method has been shown to have a high potential for eliminating trace levels of metal ions in various food and water samples. This method is characterized by being simple, sensitive, cost-effective, time-saving, and eco-friendly [48]. Gouda et al. [19] developed an SPE method using MWCNT as a solid sorbent and quinalizarin (1,2,5,8-tetrahydroxyanthracene-9,10-dione) for the removal of HMs such as Cd, Cu, Ni, Pb, and Zn in food, water, and environmental samples [19].

HMs removal using magnetic MWCNTs functionalized with 8-aminoquinoline is the most straightforward, speedy, and repeatable method. The magnetic sorbent exhibits the benefits of extraordinary sorption capacity, low limit of detection, and high enrichment element when compared to other solid phases [44] L-cysteine functionalized MWCNT exhibits very quick Cd^{2+} adsorption kinetics for online SPE of Cd^{2+} and improves the allowed concentrations of coexisting metal ions by up to 1600 times [20]. In the study by Ozcan et al. [21], a column SPE method utilizing MWCNT was recommended in the elimination of HMs includes Fe, Cu, Mn, and Pb from food, water, and plant samples. This approach demonstrated speed, precision, and simplicity [21]. This leads to the conclusion that CNTs are essential in the extraction of HMs from a range of dietary samples due to their potential to improve stability, rapid response time, selectivity, sensitivity, and detection limits.

7.3.3 Implementation of CNTs for enzyme immobilization in food science

The food sector is constantly looking for newer, more innovative solutions to satisfy consumer demands. And to answer them, over the years, enzymes have been used for the processing of raw materials into valuable products. Ranging from the enhancement of food attributes to producing cheese to pectinases for juice clarifying in the 1930s, and the employment of invertase to synthesize inverted sugar syrup using a methodology that revolutionized the use of immobilized enzymes in

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the sugar market [49,50]. The term “immobilized enzymes” refers to enzymes that have been physically localized or encapsulated within a specific area of space whilst retaining their catalytic functions, which can be deployed frequently and persistently. Immobilized enzymes are therefore preferable over their free equivalent due to their higher availability, which minimizes the requirements for downstream and purification processes. Several industrial processes, including the manufacturing of high fructose corn syrup (HFCS) in the sugar industry, require immobilized enzymes. Additionally, they help to catalyze the manufacture of various drinks like lactose-free milk and debittered beverages in addition to active packaging materials and biotechnological products [49–51].

The immobilization approach is determined by the type of enzyme and the carrier. Various methods of immobilization frequently used are: Covalent immobilization (Cross-Linking and Covalent Bonding) and noncovalent immobilization (Chelation/Metal Binding and Physical/Ionic Adsorption) are the two methods for immobilizing industrially significant enzymes on CNTs [49,52]. Immobilizing enzymes is a remarkably successful and economical process. However, due to their high price and storage issues, immobilized enzymes have limited industrial application. The spectrum of uses for these immobilized enzymes should be expanded by more research aimed at overcoming these restrictions. Thus, research projects have ignited the exploration of the possibilities of immobilizing enzymes using NT. With the development of NT, CNTs are being employed for enzyme immobilization in addition to the methods indicated above. Among these, the role of CNTs strikes the most given their chemical inertness, CNTs are the chosen nanomaterial for immobilizing enzymes. The chemistry of nanotubes and the technique used to immobilize an enzyme on a CNT affect the conjugated enzyme’s activity [49,52,53]. To demonstrate the importance of CNTs for enzyme immobilization, Vrutika and Datta [52] conducted a study to illuminate the importance of nanoimmobilization systems in organic synthesis. They functionalized an MWCNT with a solution of concentrated acids. The production of flavor-enhanced ester ethyl butyrate in the presence of n-heptane was evaluated using the immobilized lipase enzyme. The functionalized MWCNT showed great enzyme stability and reusability. Hence, proving its capacitance in the applications of organic synthesis [52]. Coming to the applications of CNTs in the enhancement of enzyme immobilization in food science and for food sensing applications. One of the research projects conducted: was the study performed by Goh et al. [54], where the researchers immobilized Amyloglucosidase on magnetic SWCNT using covalent immobilization and noncovalent immobilization. They combined iron oxide nanoparticles with SWCNTs to create magnetic SWCNT (physical adsorption). The study discovered that even after being utilized for numerous cycles during starch hydrolysis, immobilized enzymes might retain up to 40% of their catalytic activity. This implies that the enzyme is recyclable, making industrial-scale biofuel production a viable and affordable option [54].

Similarly, the study carried out by Ong and Annuar [53] revealed that MW-CNT-tannase composite served as an immobilized biocatalyst, which was created by physically adsorbing cross-linked tannase enzymes (obtained in the presence of

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glutaraldehyde) onto MWCNT. Tannase is frequently used to prepare green tea to improve its flavor. However, the research in question used a cross-linked tannase-CNT composite to increase the antioxidant capacity of green tea. The outcomes showed that the antioxidative property of green tea extract has successfully been improved through bioconversion employing an MWCNT-tannase combination. Additionally, the MWCNT-tannase composite could be recycled several times and was simple to separate from the finished product [53].

In order to enhance a tannase enzyme's catalytic behavior, Ong and Annuar worked on immobilizing it onto a MWCNT in 2018. The immobilized enzyme outperformed the free enzyme in terms of pH, temperature, and recycling, and it was able to maintain its biocatalytic activity even after 10 different applications. Strong hydrophobic interactions between the glutaraldehyde-cross-linked tannase and the MWCNT led to the immobilization [55]. Fructose is a safe and low-caloric alternative to conventional sugar and can be produced using inulinases to form fructose syrup and fructose oligosaccharides. 3-Aminopropyl-triethoxysilane (APTES) was added to MWCNTs by Singh et al., in 2019 to immobilize inulinase for effective fructose synthesis. In comparison to the free form, the immobilized inulinase shown improved thermodynamic and kinetic properties, but it did not show increased operational stability when making high fructose syrup in a batch system [56]. The implementation of CNT for immobilization in food science has been summarized in Fig. 7.4.

7.4 Role of carbon nanotubes in food sensing applications

7.4.1 Analysis of food by using CNTs detectors

Due to the rapid population growth and the subsequent rise in environmental pollution, ensuring the production of uncontaminated food has become increasingly important. As a result, food safety has become a significant focus of research in recent years. It is essential to develop diverse methodologies for food analysis to identify potentially harmful substances in food products, thereby reducing health risks. Food contaminants, including pesticide residues, food additives, and pathogens, can have serious implications for human health. Therefore, the development of new techniques for detecting hazardous materials in food is necessary to prevent foodborne illnesses and ensure the safety of the food we consume [57–59].

Recently, carbon-based nanoparticles have demonstrated promise for the creation of high-performance sensors with improved food analysis accuracy. The fabrication of biosensors using CNTs, and other carbon-based nanomaterials is used to analyze food. These Sensors have shown improvement in ease of construction and accuracy of detection by various chemical or biological agents in food. CNTs have unique electrical properties in addition to a high ratio of surface to volume and good conductivity. The creation of CNT-based detectors for the identification of various analytical substances in food is aided by all these properties. CNTs are uti-

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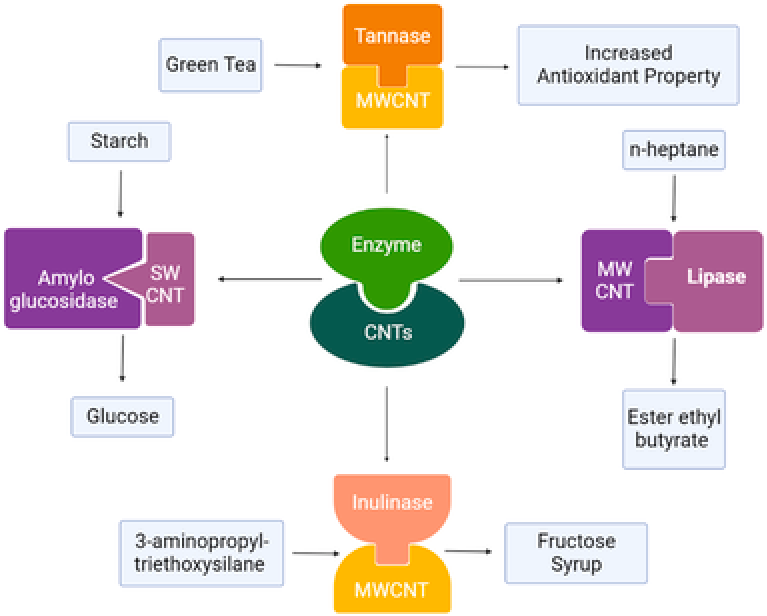

FIGURE 7.4

Implementation of CNT for enzyme immobilization in food science.

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lized to create a range of sensors for food safety because of their catalytic properties, biocompatibility, stability, and electric conductivity [57,60–62].

Acetylcholinesterase (AChE) was suggested as a sensor component for an electrochemical detector for pesticide testing based on CNT associated with the products-enhanced acetylcholinesterase activity by Chen et al. [63]. They noted that the MWCNTs increased surface area when they were loaded on glassy carbon electrodes (GCE) and then assisted in accelerating the enzymatic product's electrochemical oxidation. The enzymatic activity of AChE was also elevated by the MWCNTs. The biosensor was particularly sensitive to pesticides as well as stable and responsive as a result of these two interactions between MWCNTs. We can use this sensor to identify pesticide residue in food samples [63]. An ecologically friendly electrochemical immunosensor for the detection of *S. aureus* in food samples was created using antibody (Ab-SWCNTs) bio-conjugates. After the antigen-antibody combination was created, the Ab-SWCNTs bio-conjugate was immobilized on the electrode to detect the presence of *S. aureus*. The immunological sensor was discovered to be *S. aureus* specific. Pathogens can be found in food samples using the immunosensor that was created [64,65]. Solanki et al. [66] investigated the development of a total cholesterol sensor by immobilizing the cholesterol esterase and oxidase using glutaraldehyde as a crosslinker onto sol–gel generated silica (SiO_2)/chitosan-based MWCNTs bio-composite on an indium-tin oxide glass electrode.

With the use of this sensor, the esterified cholesterol in food samples can be determined [66].

Using a fiber optic surface plasmon resonance (FOSPR) dependent probe with the coatings of CNT-Cu nanocomposites and silver over an unclad fiber, Parveen et al. [67] created a nano-sensor that can detect nitrate in food samples. The dielectric properties of the CNT-Cu nanocomposite materials alter as a result of the interaction between the nitrate and copper nanoparticles to create ammonium ions. The shift in resonance wavelength is used to determine this change, allowing for quick and accurate detection of nitrate in each sample within 30 seconds with only 20 mL of the analyte [67]. Azo dyes are the most used coloring agents in the food industry, but these azo dyes can have harmful effects on organisms. So, there is a need to determine the presence of azo dyes in the food sample which can result in the reduction of foodborne illness due to azo dyes. Karimi-Maleh et al. [68], described that nanomaterials made of CNTs, and graphene have shown potential to detect these dyes in food samples by use of electroanalytical techniques [68].

The molecularly imprinted electrochemical sensor is a biosensor that uses molecularly imprinted polymers (MIPs) as a recognition component. This type of biosensor has high responsiveness, selectivity, dependability, ease of planning, low cost, scaling down, and ease of robotization. A GCE modified with MWCNTs and Au nanoparticles was used to build a MIP electrochemical sensor for a study on the detection of cholesterol. The MWCNT material was used to increase the detecting responsiveness of microscopically created biomimetic sensors after the MIP layer was electropolymerized onto the terminal surface. This type of biosensor has potential applications in analyzing complex food items [69]. Due to their significant surface area and distinctive electrical properties, the study by Malhotra et al. [62] showed that the detection of mycotoxin (aflatoxin) can be accomplished by utilizing biosensors based on CNTs and graphene. MWCNTs and graphene-based biosensor have shown high sensitivity and low detection limit these properties helps in the detection of food toxins during food analysis [62].

7.4.2 Role of CNTs in the detection of contaminants and toxins present in food samples

The main risks to food safety are a variety of foodborne illnesses, algae toxins which primarily cause acute illness, fungal toxins that may cause acute toxicity, as well as long-term effects like teratogenic, immune-toxic, nephrotoxic, and estrogenic effects. Food is never completely safe, and as a result, numerous complications are created. The exposure to hazardous metals like lead, cadmium, mercury, and arsenic has increased significantly as a result of industrial activity throughout the past century and beyond; these metals are now found across the food chain and demonstrate a variety of toxicities. Additionally, industrial operations generate chemicals that are outlawed, hence continuing to pollute the environment and our food. These include dioxins, various insecticides, and organochlorine substances

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such as Dichlorodiphenyltrichloroethane (DDT) etc. Hence, monitoring the presence of contaminants and toxins in food is very much required [43,57–59].

Numerous scientific organizations have emphasized the importance of addressing this issue and developing the necessary detecting tools. A research team fabricated an SWCNT biosensor with gold electrodes on the silicon wafer to identify *S. aureus*, a pathogen that commonly causes gastroenteritis by invading our system via the consumption of tainted food [70]. Similarly, in the agricultural industry, pesticides are usually employed to prevent pests from interfering with crop production. A frequently used pesticide is organophosphorus (Ops), however, after performing its function it leaves residues in crops which are hazardous to human health. An MWCNT-based biosensor was created for the rapid and accurate detection of Ops to overcome this issue (displaying the ability to detect low-concentration amounts as well) [15,59]. Moving on, primary food goods like nuts, cereals, and fruits can develop hazardous fungal metabolites like mycotoxins due to mold growth, some of which have been proven to serve as potent carcinogens like aflatoxin B1. Some of the most notable mycotoxins that are now recognized are aflatoxins, deoxynivalenol (DON), zearalenone, ochratoxin, fumonisin, and patulin. The Aspergillus, Penicillium, and Fusarium genera are frequently responsible for producing these toxins. Modified Quick Easy Cheap Effective Rugged and safe (QuEChERS) adsorbents with Fe_3O_4-MWCNTs were used to detect 20 mycotoxins in grains, with acceptable linearity, good recovery, accuracy, and sensitivity [14]. Additionally, CNTs have been employed to build electrochemical enzyme sensors and immunosensors due to their ability to enable electron transfer processes with electroactive species at low overpotentials. In order to make Electrochemiluminescence (ECL) more practical for immunoassays, a study group developed a straightforward and portable point-of-care immunosensor using a straightforward cooled charge-coupled device (CCD) detector in conjunction with CNTs for primary antibody immobilization. A combination of ECL, CNT, and CCD detector technologies improves the detection of *Staphylococcal enterotoxin B* in food [13]. Henceforth, the exploitation of modified CNTs by combining them with varied techniques, for the efficient detection of food contaminants and toxins that got deposited into food products has proven quite successful [13–15]. Thus, concluding that CNTs play an important role in the determination of contaminants and toxins in various food samples.

7.4.3 Role of CNTs in the detection of amino acids (glutamate) in food samples

L-Glutamate or also known as monosodium glutamate (MSG), is a nonessential amino acid and a neurotransmitter that is naturally present in protein-rich foods such as mushrooms, milk, meat, cheese, fish, and various vegetables. It is essential for several physiological and pathological processes in the brain, including stabilization, synapse formation, learning, and cognition. Apart from its acquisition from external sources, it can also be produced in our body as it is vital for brain function

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and metabolism. MSG also acts as a taste enhancer and a flavoring agent. Therefore, it is added to several food items such as snacks, poultry, soups, processed meats, and seafood, etc. However, excessive amounts of glutamate intake may cause overexcitation of the nerve cells which in turn damages brain cells causing psychiatric disorders like Parkinson's disease, schizophrenia, depression, Alzheimer's disease, and death in extreme scenarios. Oddly, the presence of lower amounts of glutamate in our body may result in insomnia, mental exhaustion, and low energy levels and might hinder our concentration efficiency. Hence, it is necessary to determine its concentration in the items we consume; to better understand how much we are consuming in our daily life and what is the optimal amount of glutamate levels within a human body [71–76]. There are numerous ways to measure glutamate levels, however they are frequently expensive and require experienced operators. A quick, easy, and sensitive alternative is provided by electrochemical biosensors; however, these have drawbacks such poor charge transfer and low sensitivity. Although nonenzymatic biosensors have been created, their selectivity for detecting low MSG amounts is weak. To create more precise and sensitive biosensors for glutamate detection, improvements are required. [71–75,77].

By incorporating nanomaterials in the electrochemical sensors, even minute concentrations of analytes can be detected. Thus, improving the electrical conductivity and surface area. Recent studies have shown that CNT promoted the efficient transfer of electrons between electrodes and biomolecules. Furthermore, they also enhanced the electroanalytical reactivity of biomolecules. Biosensors made with polypyrene (PPy), polyaniline, reduced graphene oxide, and metal nanoparticles have improved electrocatalytic activity compared to pure PPy. Maity et al. [72], reported that a biosensor made with glutamate oxidase immobilized platinum nanoparticle decorated MWCNT/PPy composite showed lower detection level, faster response, better storage stability, and high sensitivity [72]. Similarly, the biosensor fabricated on the surface of thionine-SWCNT by immobilizing glutamate dehydrogenase, showed a low detection limit, high sensitivity, good stability, a rapid response, higher biological affinity, and repeatability [73]. Additionally, Chakraborty et al. [77] managed to develop a biosensor for the detection of glutamate by incorporating MWCNT and using glutamate dehydrogenase, redox mediator meldola's blue, biopolymer chitosan [77]. In 2012, Gholizadeh et al., developed a biosensor for the detection of glutamate in various food samples and healthcare fields. The biosensor was fabricated using glutamate dehydrogenase/vertically aligned CNTs and demonstrated a low detection limit, high sensitivity, stability, and good selectivity [75]. It has been demonstrated that a biosensor made with glutamate oxidase adsorbed on a MWCNT is a straightforward and trustworthy device with a low detection limit in the nanomolar range, good stability, operation, and a quick response time. As a result, it appears that CNTs are essential for identifying amino acids like glutamate in various food samples [12].

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7.4.4 Role of CNTs in the determination of vitamins (Vitamin B9 and Vitamin C) concentration in various food samples

Vitamins are essential micronutrients that the body requires to function regularly and to sustain excellent health. Vitamins come in two varieties: fat-soluble and water-soluble. Vitamin C and the B vitamins are two examples of water-soluble vitamins. There are four fat-soluble vitamins: A, D, E, and K [78]. Folic acid (FA) and ascorbic acid (AA) are essential water-soluble vitamins that cannot be produced by humans and are found in fruits and vegetables. FA is crucial for cell division and growth, while AA is an antioxidant important for collagen maintenance in the body. Deficiencies in AA lead to scurvy, while FA deficiency can lead to psychiatric disorders, cancer, coronary heart disease, metabolic syndromes, diabetes, etc. However, excessive levels of both vitamins can also have side effects. Therefore, it is important to maintain proper levels of these vitamins in the body by checking their concentrations in food samples before consumption [10,11,79–83].

The quantities of AA and FA in food can be detected by several methods, including fluorimetry, chemiluminescence, chromatography, spectroscopy, and enzymatic approaches. These techniques can, however, be expensive and require complicated steps. Using CNTs can increase sensitivity and make it easier to find AA and FA in a range of dietary samples [10,11,79,81–85]. The electrochemical method was proven to be effective for the determination of AA [86]. Conducting oxidation at a higher potential detects the AA level at the GCE. However, due to the possibility of some electroactive species (dopamine and uric acid) being present in biological fluids, they may oxidize and produce an interfering current at that potential. Dehydroascorbic acid is created when AA is oxidized; however, because it is highly absorbed onto the electrode surface, it causes fouling of the electrode and has poor precision [80]. Although there was an effort to improve the performance by film-modified electrodes using nanomaterials and conducting polymers to detect AA levels, it showed some better results, but despite this, there were some drawbacks such as poor long-term stability, contamination, and passivation of electrodes [81].

These can be avoided if the electrodes are carbon composite electrodes. These are commonly employed in electrochemical sensors since they are inexpensive to produce and simple to do so. Due to their sizable surface-specific area, superior electronic conductivity, and robust mechanical strength, CNTs are appropriate for electro-analysis. Additionally, it can make the electrode and electrochemical species' electron transfers easier [84]. A composite electrode made of MWCNT, and ionic liquid (IL) was also used in another work by Liu et al., in 2019 to measure the amounts of FA in edible oils. Due to the composite electrode's superior electrocatalytic activity and stability, FA could be detected with a high degree of sensitivity and selectivity. This method could be used to determine FA quickly and precisely in a variety of dietary samples, including edible oils. Therefore, combin-

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ing the usage of CNTs with ILs can provide a useful and efficient method for determining the quantities of AA and FA in food samples [10].

To determine the levels of AA in oranges, Motsaathebe and Fayemi [85] observed that screen-printed carbon electrodes built with MWCNT-antimony oxide nanoparticles enhanced electron transport and electrocatalytic reaction. The sensor showed a long shelf life, antiinterference behavior, and was simple, inexpensive, highly selective, and gave accurate results quickly [85]. The composite electrode created by combining MWCNT and cobalt phthalocyanine on a GCE demonstrated outstanding electrocatalytic, low detection level, high repeatability, quick reaction, and good stability in the detection of AA, according to Zuo et al. study [82]. Ngai et al., created a technique for the volumetric detection of AA using a GCE altered with SWCNT/Zinc Oxide in 2013, and it has demonstrated excellent sensitivity [31]. An MWCNT/polyaniline-modified Au electrode was created by Chauhan et al. [83] to detect AA in fruit juices, vitamin C supplements, etc. This biosensor has a quick response, quick detection, and stable storage [83]. Moreover, it is stated that through oxidation and reduction processes the FA concentration can be determined with the anodic and cathodic intensities of current as it is an electroactive compound. MWCNT-modified electrodes are easy to use in electrochemical applications such as FA and AA because of their excellent mechanical characteristics, outstanding electrical conductivity, and bending strength [83,87].

The research by Winiarski et al. [79] found that the determination of FA using a composite material made of MWCNTs and nickel hydroxide (f-MWCNT-Ni$(OH)_2$) produced accurate results when compared to molecular absorption spectrometry. The 1-octyl-3-methylimidazolium hexafluorophosphate-based biosensor (OMIMPF6-SWCNT) on a GCE demonstrated good sensitivity and repeatability to detect FA in a variety of food samples, including milk and fruit juices [88]. The nanocomposite made of MWCNT on a GCE helps in the determination of FA [87]. Application of MWCNT (on GCE) in ion chromatographic electrochemical detection of FA improved the detection sensitivity and eliminated the procedures of complicated derivatization [11]. Therefore, it can be said that CNTs are crucial in determining the presence of vitamins (AA and FA) in different dietary samples.

7.4.5 Role of CNTs in the determination of carbohydrates (glucose and fructose) in various food samples

Along with proteins and lipids, carbohydrates are one of the necessary macronutrients in the human diet. They are an essential source of energy for various metabolic activities. Naturally, they are present in vegetables, fruits, legumes, and fibers. Some examples of carbohydrates are glucose, fructose, sucrose, lactose, etc. A high. amount of carbohydrate intake may cause tooth decay, plaque formation, obesity, and disorders such as cardiovascular disease, etc. Whereas a low amount of carbohydrates in the diet corresponds to hypoglycemia, leading to ketosis where the body starts burning fat for energy. Both metabolic and physiological processes are affected by taking increased or decreased levels of carbohydrates in the diet. There-

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fore, it is necessary to take the right amount of carbohydrates in the human diet for a healthy life and need a good biosensor that can give accurate results quickly [89–92].

Traditional glucose detection techniques including electrophoresis, chromatography, microchip, spectrophotometry, and titration take a lot of time, require expensive equipment, and are labor-intensive. The lack of fluorophore and chromophoric ligands in glucose also limits the use of spectrophotometric approaches. Utilizing biosensors is a more straightforward, affordable, and selective method for detecting sugars, which can quickly monitor raw materials and food processing activities. [9,93–95]. The incorporation of nanomaterials like CNT in the Copper electrode for capillary electrophoresis microchip for carbohydrate detection displayed stability, bulk modification, surface renewability, flexibility, and increased sensitivity when compared to detectors based exclusively on copper or CNT. This sensor can identify carbohydrates in a variety of dietary samples, including glucose, galactose, fructose, sucrose, etc. [89]. Glucose (Glc) is a common monosaccharide found in various food samples and is detected through enzyme-less or enzyme-based sensors. Enzyme-based sensors, particularly those using glucose oxidase (GOx) enzyme, are commonly used due to their stability and affordability. In the presence of oxygen, the GOx enzyme initiates the oxidation of glucose to gluconolactone, which subsequently undergoes hydrolysis to produce gluconic acid. Copper-based electrodes are preferred for glucose detection due to their higher catalytic activity, stability, detection limits, and response ranges [93,96].

CNTs and glucose oxidase were combined to create enzyme-based biosensors, which demonstrated properties like simplicity, low cost, durability, sensitivity, selectivity, and versatility in the determination of Glc concentration in soft drinks and beverages [8]. There are certain limitations to using enzyme-linked biosensors, such as instability, poor repeatability, and an insufficient electrical connection between the electrode and the enzyme active site. Pulsed electrodeposition of copper metal particles in self-assembled CNT films produced an enzyme-free biosensor with improved stability, sensitivity, and reproducibility [93]. But the Platinum-lead alloy nanoparticles electrode deposited on MWCNT can be used to detect the Glc concentration. In neutral solutions, this combination showed good sensitivity, electrocatalytic activity, and selectivity with a low detection limit [94].

A biosensor utilizing CNTs in the electrode with fructose dehydrogenase and osmium redox polymer was developed to detect fructose concentration in various food samples. Excessive consumption of fructose can lead to obesity, nonalcoholic fatty liver disease, and type 2 diabetes. The biosensor is appropriate for use in the food industry to measure the quantity of fructose in various fruit juices, honey, energy drinks, and soft drinks since it is straightforward, affordable, and produces accurate results in a shorter amount of time [95]. In the Tominaga et al. [9] work, an MWCNT composite that was produced on a platinum electrode was used to determine the fructose concentration. Biosensors made of immobilized enzymes are a fast and selective method for fructose determination. For instance: A CNT paste electrode is combined with a 3,4-dihydroxy benzaldehyde electropolymerized film,

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and fructose dehydrogenase enzyme is immobilized at the top of the electrode surface on an immobilon membrane to create a biosensor. This biosensor exhibits superior accuracy, strong sensitivity, high stability, low detection limit, and good repeatability for determining the presence of fructose in food samples like honey when compared to GCE and graphite electrodes. This is due to the CNTs' substantial surface area, which improved the sensor's performance [97]. Therefore, it can be said that CNTs are crucial for identifying carbohydrates (such as fructose and glucose) in a variety of food samples. The role of CNTs in food sensing applications have been summarized in Fig. 7.5 and CNT's role in food science and food sensing applications have been tabulated in Table 7.3.

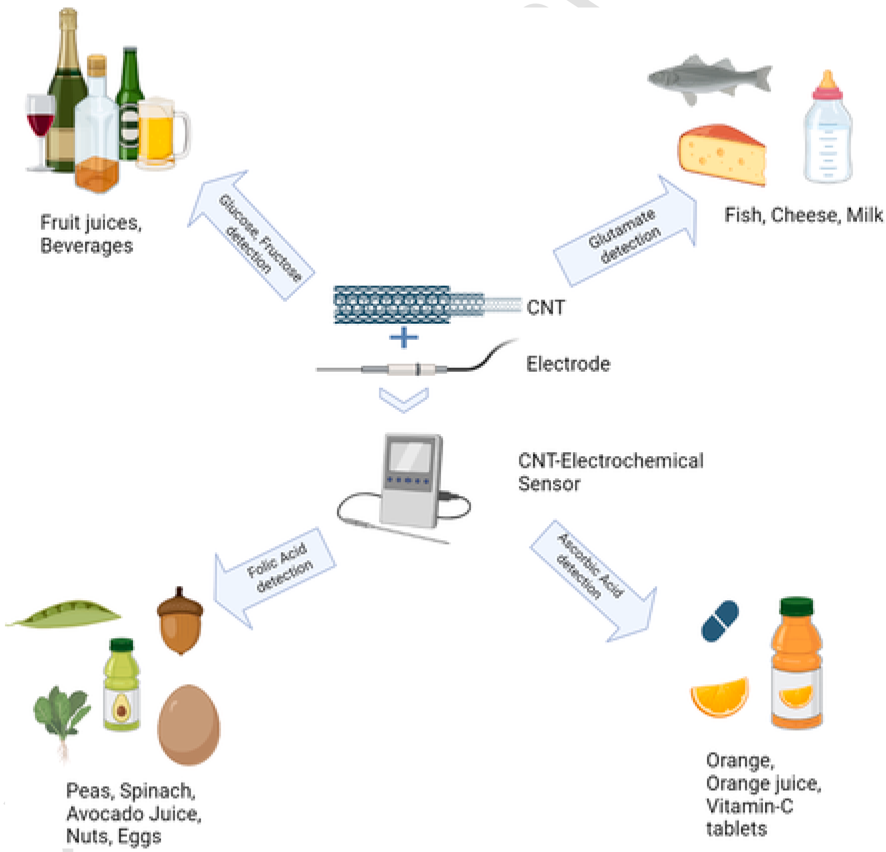

FIGURE 7.5

Role of CNTs in food sensing applications.

TABLE 7.3 Role of CNTs in food science and food-sensing applications.

S.L No	CNT-based nanocomposite	Applications	References
1	CNTs coated on Ag-doped TiO_2 nanoparticles	High efficacy against *Staphylococcus aureus* and *E. coli* germs. Aids in extending the food's shelf life.	[16]
2	PHBV-grafted MWCNTs	It is used in food packaging	[38]
3	The antimicrobial packaging used CNTs and allyl isothiocyanate.	Aids in extending the food's shelf life.	[18]
4	Nanocomposites with low-density polyethene films of CNTs	Helps in Food preservation	[39]
5	SWCNTs	Aids in the packaging of food and its preservation.	[17]
6	Acetylcholinesterase (AChE) incorporated with MWCNT sensor	Aids in finding pesticide residues in food samples.	[63]
7	Immobilization of Ab-SWCNTs	Assists in finding residual pesticides in food samples.	[64]
8	MWCNT/chitosan/silica-derived sol-gel composite	Estimation of esterified cholesterol in food samples.	[66]
9	A fiber optic SPR(FOSPR)-based probe with silver and CNT-Cu coatings	Aids in nitrate determination in food sample	[67]
10	CNT-based, molecularly imprinted electrochemical sensor	Analysis of iodine and fluorine traces in complex food products' matrix	[69]
11	MWCNTs and graphene-based biosensor	Helps in the detection of food toxins during food analysis	[62]
12	MWCNT impregnated with 2-(2-benzothiazole) orcinol	Helps to remove heavy metals from different food and water samples.	[48]
13	Magnetic MWCNTs functionalized with 8-aminoquinoline	Helps in the extraction of heavy metals	[44]
14	MWCNT as a solid sorbent and quinalizarin	Helps in the extraction of HMs from environmental, water, and food samples.	[19]
15	L-Cysteine functionalized MWCNT	Helps in the adsorption of Cd^{2+} in food samples	[20]

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S.L No	CNT-based nanocomposite	Applications	References
16	Incorporation of MWCNT in column SPE	Helps in the elimination of HMs in food, water, and plant samples	[21]
17	Antimicrobial enzymes immobilized on the surface of food packaging material	Increasing the food's shelf life if it is not sanitary, cold, or scarcely processed	[98]
18	Immobilized amyloglucosidase on magnetic SWCNT	Helps in the hydrolysis of starch	[54]
19	Immobilized MWCNT-tannase	Increase the antioxidant capacity of green tea.	[53]
20	SWCNT biosensor with gold electrodes on the silicon wafer	Helps in the determination of *S. aureus* in food samples.	[70]
21	Acetylcholinesterase-MWCNT biosensor	Helps in the detection of pesticides (Ops)	[15]
22	Modified QuEChERS adsorbents made of a variety of magnetic (Fe_3O_4) nanoparticles with MWCNT	Aids in the identification of 20 mycotoxins in cereals, including aflatoxin B1, aflatoxin A, aflatoxin B2, ochratoxin, fumonisin, and patulin.	[14]
23	ECL, CNT, and CCD mix sensor	Helps in the detection of *Staphylococcal enterotoxin B* in food samples	[13]
24	Biosensors fabricated with MWCNT/PPy composite	Helps in the determination of glutamate in various food samples.	[72]
25	Thionine-SWCNT by immobilizing glutamate dehydrogenase	Helps in the determination of glutamate in various food samples	[73]
26	Biosensor made of Glutamate oxidase by adsorbing on an MWCNT.	Helps in the determination of glutamate in various food samples	[12]
27	Biosensor made of glutamate dehydrogenase/vertically aligned CNTs	Helps in the detection of glutamate concentration in various food samples, and healthcare fields.	[75]
28	Incorporating MWCNT and using glutamate dehydrogenase, redox mediator meldola's blue, biopolymer chitosan.	Helps in the determination of glutamate.	[77]

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S.L No	CNT-based nanocomposite	Applications	References
29	IL-SWCNT electrode	Helps in the detection of AA in food samples.	[10]
30	Carbon electrodes fabricated with MWCNT-antimony oxide nanoparticles	Helps in the detection of AA in food samples.	[85]
31	MWCNT with cobalt phthalocyanine on a GCE	Helps in the detection of AA	[82]
32	MWCNT/polyaniline-modified Au electrode	Helps in the detection of AA in fruit juices, vitamin C tablets	[83]
33	GCE modified with SWCNT/zinc oxide	Helps in the volumetric detection of AA	[31]
34	Composite material made by MWCNTs and nickel hydroxide	Helps in the detection of FA in food samples	[79]
35	Incorporation of CNT in the Copper electrode for capillary electrophoresis microchip	Helps in the detection of carbohydrates such as glucose, galactose, fructose, and sucrose.	[89]
36	Ionic liquid OMIMPF6-SWCNT on a GCE	Helps in the detection of FA in different samples such as fruit juices, milk, etc.	[88]
37	MWCNT on a GCE	Helps in the detection of FA	[87]
38	MWCNT (GCE) in ion chromatographic electrochemical	Helps in the detection of FA	[11]
39	Incorporating CNTs and glucose oxidase in a conventional GCE	Helps in the detection of Glc in soft drinks and beverages	[8]
40	Pulsed electrodeposition of copper metal particles in self-assembled CNT films results in an enzyme-free biosensor.	Helps in the detection of Glc in food samples.	[93]
41	Platinum-lead alloy nanoparticles electrode deposited on MWCNT	Helps in the detection of Glc in food samples.	[94]
42	Incorporating CNT in the electrode with fructose dehydrogenase and osmium redox polymer	Helps in the detection of fructose in various fruit juices, honey, energy, and soft drinks	[95]
43	Synthesized MWCNT composite on a platinum electrode	Helps in the detection of Fructose concentration	[9]

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S.L No	CNT-based nanocomposite	Applications	References
44	Combining a 3,4-dihydroxy benzaldehyde electropolymerized sheet with a CNT paste electrode and immobilizing fructose dehydrogenase enzyme	Helps in the detection of fructose in food samples such as honey.	[97]

7.5 Carbon nanotubes: current scenario and prospects

Recent NT developments have the potential to completely transform the food and agriculture industries by enabling the exact manipulation of food molecules to enhance a variety of food quality factors. By understanding the structure and interactions of food components, scientists can create healthier, tastier, and safer food products. NT might assist in developing low-cost, environmentally friendly processes, as well as more accurate, lightweight food processing equipment and "smart" packaging materials. Additionally, NT enables the creation of innovative delivery systems and sensors for pathogen detection in agricultural products, ensuring food safety. Additionally, in order to solve environmental issues, NT can help transform agricultural resources and food waste into energy and usable byproducts. These developments may enhance agricultural production and agricultural research, which would be beneficial to the food system [99,100].

The National Science Foundation (NSF) predicted that in less than 10 years, goods manufactured with NT will have a $1 trillion economic impact on the world and that two million people will be employed in the NT sector alone [101]. Many of the top food corporations in the world, including Kraft, Unilever, Heinz, Nestle, and Hershey, are now making significant investments in NT-related projects [102]. Although food applications of NT are still in their infancy, there is a lot of excitement and expectation surrounding this technology, individuals at the First International Food Nanotechnology Conference in 2006 (which was hosted by the Institute of Food Technologists) agreed. The food sector is currently looking for prospects and the most promising advances in NT in order to greatly improve food production and food products. Future applications of NT in the food industry look very promising, particularly in the following areas:

- Promotion of health through diet by transporting bioactive substances in food matrices.
- The development of new, more useful ingredients that might be used to make dishes with unique flavors and sensations.
- The creation of foods with improved functionality that might be used to create dishes with novel flavors and textures.

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- The creation of materials with microbial resistance that could be utilized to make surfaces that come into touch with food.

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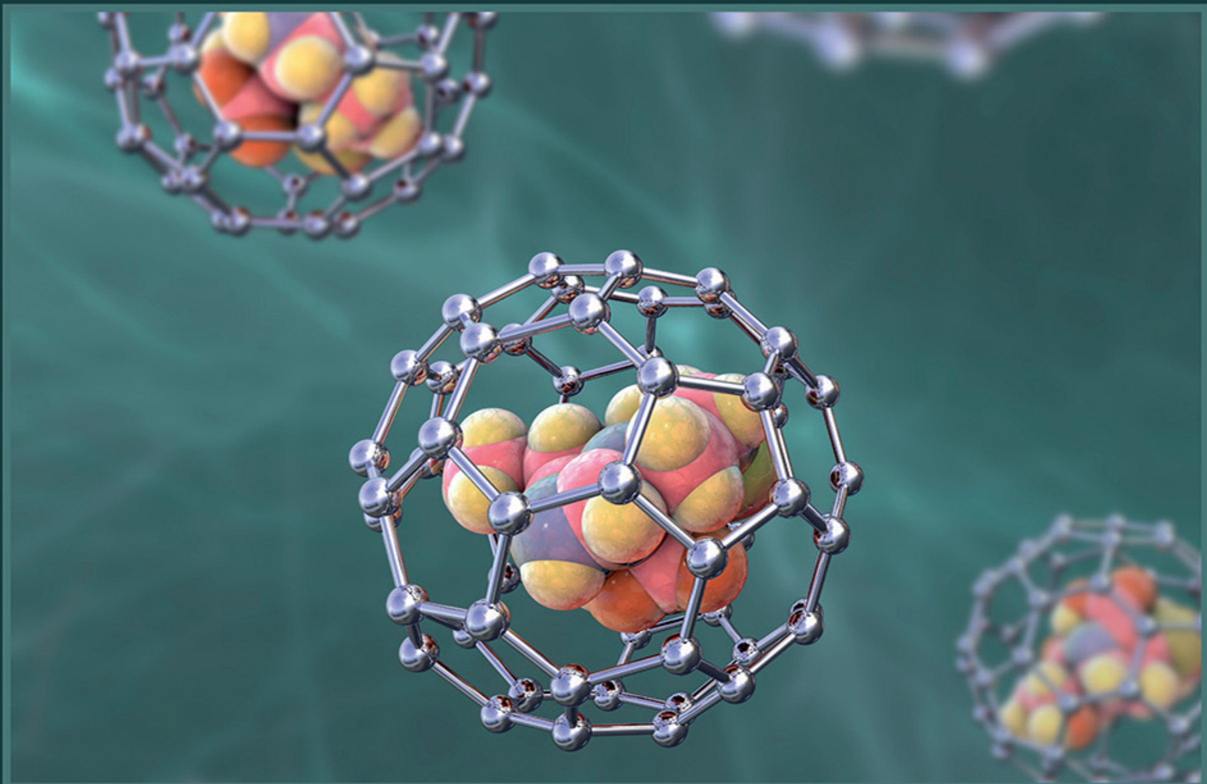

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CHAPTER

5 Implications of caged molecular structure of buckminster fullerenes in food sciences and industry applications

Mohammad Zaki Shamim[1], Pampi Deka[1], Yugal Kishore Mohanta[2], Bishwambhar Mishra[3], Kunal Biswas[4] and Awdhesh Kumar Mishra[5]

[1]*Department of Food Nutrition and Dietetics, Faculty of Sciences, Assam Down Town University, Guwahati, Assam, India*

[2]*Nano-Biotechnology and Translational Knowledge Laboratory, Department of Applied Biology, School of Biological Sciences, University of Science and Technology Meghalaya (USTM), Baridua, Meghalaya, India*

[3]*Department of Biotechnology, Chaitanya Bharathi Institute of Technology, Hyderabad, Telangana, India*

[4]*Centre for Nanoscience & Nanotechnology International Research Centre, Sathyabama Institute of Science and Technology, Chennai, Tamil Nadu, India*

[5]*Department of Biotechnology, Yeungnam University, Gyeongsan, South Korea*

5.1 Introduction

Graphite and diamond are two examples of the many different forms that carbon may take in the natural world. Carbon is the most abundant element on Earth. Fullerenes are the fourth type of allotrope that carbon can take. Fullerenes are spherical molecules that are soluble in a wide variety of organic solvents. This is in contrast to the extended solid-state structures of graphite and diamond. This characteristic enables a wide variety of chemical manipulations to be carried out [1].

A fullerene is a structure made of carbon that has a fused ring system and is composed of pentagons and hexagons (see Fig. 5.1). EijiOsawa of Japan is credited with making the initial suggestion for the buckyball. He noticed that corannulene, which is a cyclopentane ring fused with five benzene rings, was a component of the football framework, and he postulated that the full structure could actually exist. At Rice University in 1985, a group of researchers led by Harold Kroto and including Richard Smalley, Robert Curl, James Heath, and Sean O’Brien [3] successfully created the first fullerene molecule by synthesizing

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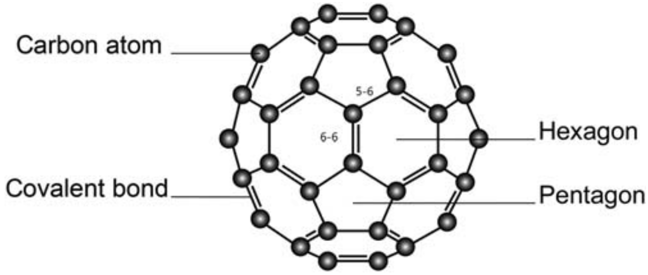


FIGURE 5.1

Schematic representation of a fullerene C_{60} molecule contains two different kinds of bonds: 6-6 and 5-6. Courtsey: Rondags et al., [2].

From Mojica M, Alonso JA, Méndez F. Synthesis of fullerenes. J Phys Org Chem. 2013;26(7):526–539.

buckminsterfullerene (C_{60}). These researchers chose to honor R. Buckminster Fuller, an architect who designed a geodesic dome with a similar shape, by naming the newly found molecule after him.

Fullerenes are made up of fused pentagons and hexagons (see Fig. 5.1 for a visual representation). Two of its members, C_{60} and C_{70}, are particularly easy to get your hands on. This molecule's great symmetry is an essential characteristic. According to research by Roger Taylor and Walton, the C_{60} molecule is made up of 60 carbon atoms, 12 pentagons, and 20 hexagons. Double bonds (6−6 and 5−6 in C_{60}) are extensively conjugated, and all rings are fused. There are 120 symmetrical operations, such as rotation about an axis and reflection in a plane, that map the molecule onto itself, contributing to the molecule's high degree of symmetry. When a carbon atom is inserted at each vertex of a molecule, the structure of the C_{60} molecule, which is stabilized by resonance and seems to be aromatic, is produced. This structure has all valences met by a pair of single bonds along with a double bond [4]. Fullerane, a fully saturated fullerene (e.g., the hydrocarbon $C_{60}H_{60}$) and fullerene-like compounds, such as Heterofullerene, Norfullerene, Homofullerene, and Secofullerene (Fig. 5.2), are other variants of fullerene [6].

5.2 Fullerenes: basic characteristics

When compared with impure fullerenes, pure ones have superior close packing. C_{60} derivatives exhibit a broad solubility spectrum [7]. Some bromo compounds are very poorly soluble, while fluorinated derivatives are substantially more so. When compared with diamond (3.51 g/cc), the density of fullerenes is quite low at only 1.65 g/cc. Fullerenes have a stability window of up to 1000°C. As fullerenes are composed entirely of sp^2-hybridized carbons, they exhibit a high electron-attracting -I effect, making them reactive with nucleophiles. Reactivity

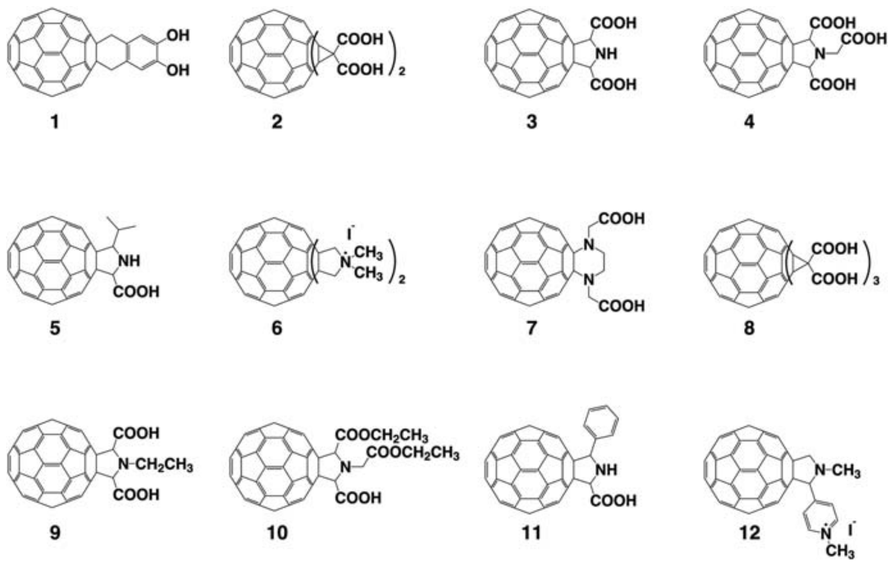


FIGURE 5.2

Derivatives of fullerene that are structurally distinct from one another.
Courtsey: Piotrowski et al. [5].

From Malhotra BD, Srivastava S, Ali MA, Singh C. Nanomaterial-based biosensors for food toxin detection. Appl Biochem Biotechnol. 2014;174(3):880–896.

increases with increased strain energy. There are several types of reactions that can occur with fullerenes [8], including reduction, oxidation, hydrogenation, halogenation, nucleophilic reactions, radical reactions, transition metal complex reactions, regioselective reactions, and more. Light and oxygen can cause fullerenes to deteriorate or break down [9]. C_{60} decays as a result of the intersystem crossing from the higher-energy singlet excited state to the lower-energy triplet excited state. Multiple deactivation mechanisms, such as ground state quenching, quenching by molecular oxygen, and electron transfer to molecules, are capable of removing the triplet excited states from their excited states.

5.2.1 Stability of fullerenes

The stability of fullerenes is affected by electron localization and ring strain. Using the Huckel rule [10], we can predict that only C_{50} and C_{70}, out of a total of five fullerene derivatives (C_{50}, C_{60}, C_{70}, C_{80}, and C_{84}), are aromatic, with C_{60} being the least aromatic. Only C_{60} was shown to be more aromatic and extremely stable than any other molecule tested, consistent with Huckel's rule, which states that aromaticity is more likely to occur in spherical systems than in planar ones. The isolation of C_{60} 12 pentagons from one another contributes to the molecule's

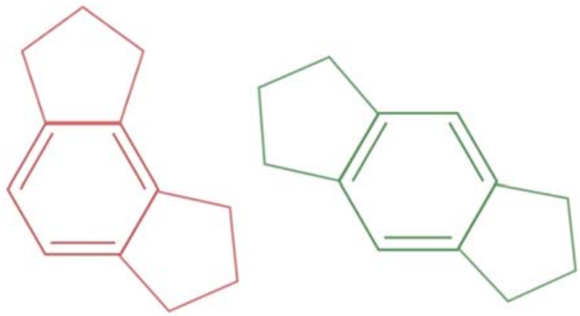


FIGURE 5.3

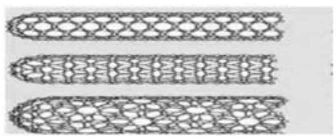
Stability of fullerenes.

exceptional stability [11]. If there are no double bonds in a five-membered ring, but there are minimal bond orders in a six-membered ring, then the inverse is true. Bond order minimization in five-membered rings is achieved through the fusion of rings at meta positioning (a) with a hexagonal ring, as seen in Fig. 5.3. Due to the para connection between the two pentagonal rings, C_{60} will become unstable if the criteria of minimizing of bond orders are not met. Type (b) arrangements are substantially more common in higher fullerenes such as C_{70}, but they are less stable than the five-arrangement structure of C_{60}. What this means is that the more carbon atoms there are, the less stable the compound will be.

Diamond and graphite are two allotropic forms of carbon that can be found in nature. Fullerenes, a third type of carbon, were found in 1985 [3]. Researchers led by Smalley, Kroto, and Curl tried to recreate the conditions seen in red giant star atmospheres, where carbon nucleates. The solid graphite surface was evaporated into plasma consisting of atoms and free ions after being irradiated by the laser in the experiment. The impact with the helium atoms cooled down the unbound atoms and ions. The collision resulted in the formation of clusters of carbon atoms with varying densities. Mass spectrometry analysis revealed that 60 and 70 carbon clusters predominated, with the majority consisting of 60 carbon atoms. Scientists initially struggled to mass-produce enough fullerenes. Only about 10−15 g had been successfully prepared. However, after another 5 years, new high-yielding preparative procedures for fullerenes were established by Kratschmer and Huffmannand H. W. Kroto, Allaf, and Balm [12,13].

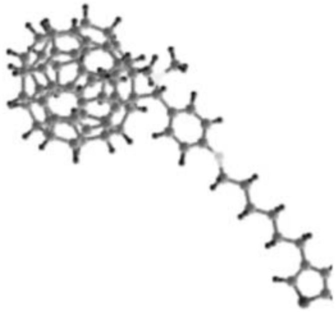
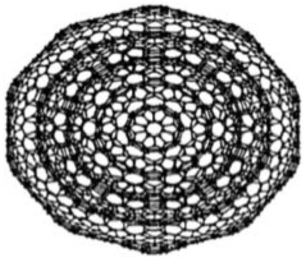
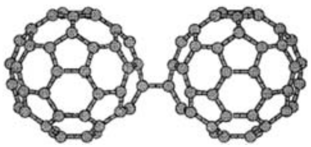
The scientists have given the newly discovered carbon cluster the name “Buckminsterfullerene” in honor of the architect Richard Buckminster Fuller, who designed a dome in 1967 with the same form as the molecule. Due to the widespread acclaim and enthusiasm for fullerenes among researchers, the three scientists responsible for their discovery shared the 1996 Nobel Prize in Chemistry. Subsequent research revealed that fullerenes can be found in trace amounts in both interplanetary dust and Earth's geological formations. Shunga (Russia), New Zealand, and Sudbury (Canada) are only a few of these locations [14–16].

5.2.2 Types of fullerenes

S. No.	Types	Description	Representation	References
1.	Buckyball clusters	The C_{20} is the least common number, and the C_{60} is the most common. Since the sphere of the buckyball is hollow, it is possible for additional atoms to become caught inside of it.	 Buckyball clusters.	[17]
2.	Nanotubes	Electronics manufacturing often makes use of hollow tubes of very small diameters with either a single wall or several walls.	 Nanotubes.	[18]
3.	Mega tubes	Nanowires are characterized by more variable dimensions than nanotubes, including a bigger diameter and walls of varying thicknesses; their applications include the transport of a wide range of molecules of varying sizes.	 Mega tubes.	[19]

(*Continued*)

Continued

S. No.	Types	Description	Representation	References
4.	Polymers	Under conditions of high pressure and temperature, a chain, either two or three dimensional, is created.	 Polymers.	[20]
5.	Nano "onions"	Buckyballs are spherical particles that are composed of many layers that surround the core. The diameter ranges from 3 to 5 nanometers on average; this range is advised to used as a lubricants.	 Nano "onions."	[21]
6.	Linked "ball-and-chain" dimers	Two buckyballs connected to one another by a chain of carbon.	 Linked ball and chain dimers.	[22]

5.2.3 Synthesis of fullerenes

As part of their research into how long-chain carbon molecules develop in space, Kroto et al. [3] evaporated graphite using laser irradiation, resulting in a remarkably stable cluster of 60 carbon atoms [3]. The chemistry of C_{60} has become widely studied because of this experiment. Krätschmer and colleagues [12] established the first way to obtain C_{60} in useable amounts, some 5 years after its discovery. Graphite rods are heated resistively in an atmosphere of He until they evaporate. Access to large quantities of C_{60}, thanks to the efforts of Krätschmer and colleagues, revolutionized the study of fullerenes. The development of fullerene chemistry was also made possible by their synthesis.

Nonetheless, the yields from this approach are poor (about 1%), and the reaction conditions are severe (approximately 1300°C and 1 kbar) [23]. While C_{60} and C_{70} can be made with this technology, larger fullerenes such as C_{84} are only produced in negligible quantities and must be purified using extensive procedures (more than 20 HPLC cycles for C_{84}). The reaction is too chaotic to allow for the isolation of a single fullerene or the isolation of a single isomer [24].

Since then, there has been a push in the scientific community to develop more precise techniques for the efficient, low-cost synthesis of bigger fullerenes and targeted isomers. Today, however, graphite is vaporized by pyrolysis, radio-frequency-plasma, or arc-discharge-plasma processes to generate fullerenes on a commercial scale [25]. Similar drawbacks to Krätschmer's approach are shared by all of these alternatives. Several procedures, including synthesis of the fullerenes, separation, purification, and functionalization, are shown in Fig. 5.4 for the creation of functionalized fullerenes for application, for example, in organic solar cells. The economic and environmental effects of fullerene synthesis have been examined by Anctil and colleagues [26], who quantified the total raw material and the embodied energy required for fullerene manufacture. Fullerenes are expensive to produce due to the large amount of energy required for their synthesis and separation (up to 106.9 GJ/kg of C_{60}); for comparison, the average annual electricity consumption for a US home in 2010 was about 41 GJ [27], and the even larger amount of energy required for their purification and functionalization,

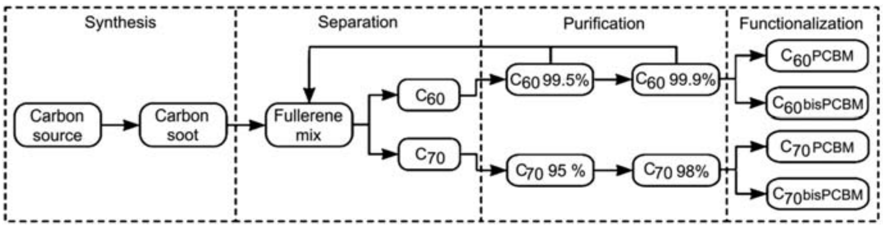


FIGURE 5.4

A schematic showing how modified fullerene compounds can be made and used in organic solar cells. The fullerenes must first be synthesized before they can be separated, purified, and functionalized. Here, C_{60} fullerenes are functionalized by adding one or two methyl ester functional groups, yielding [6,6]-phenyl-C_{61}-butyric acid methyl ester (PCBM) or bis [6,6]-phenyl-C_{61}-butyric acid methyl ester (bis-PCBM), and C_{70} is functionalized in a similar fashion.

Anctil A, Babbitt CW, Raffaelle RP, Landi BJ. Material and energy intensity of fullerene production. Env Sci Technol. 2011;45(6):2353–2359.

the total energy can increase by a factor of 3. For this reason, many various approaches have been tried to synthesize C_{60}, and many different theoretical approaches have been offered to account for the synthesis process.

5.2.3.1 Models to explain the formation of fullerenes

Scientists have attempted to explain fullerene production ever since their discovery. According to general theory, fullerenes are created when carbon is vaporized into its smallest units, carbon atoms and, most likely, carbon dimers. These smaller units then undergo a series of processes and, within a narrow pressure and temperature window, reunite to form fullerenes [3]. However, this straightforward concept does not provide a sufficient description of the process by which fullerenes are formed, and alternative theories have been presented. Goroff [28] previously reported on models for fullerene production.

Fullerenes were first explained using the icospiral particle nucleation method [29,30]. As can be seen in Fig. 5.5, the icosahedral nucleation in this model begins with a C_{20} molecule that resembles corannulene but has a pentagon surrounded by five hexagons. By accumulating microscopic carbon particles that are cleaned up by adsorption on the surface of such shells, this highly reactive structure expands and tends to form nautilus-like open spirals [31,32]. Fullerenes can be explained by the fact that they occur only statistically rarely, when a network

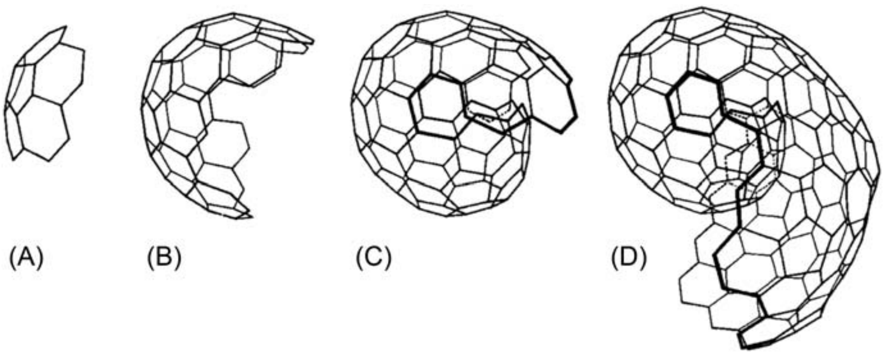


FIGURE 5.5

The creation of fullerenes begins with an icosahedral nucleation mechanism. The procedure begins with a C_{20} (A) corannulene in the shape of a saucer. Small carbon fragments accrete into this reactive cluster, allowing it to expand. In (B), a shell is split in half. As seen in (C), the second shell is growing under epitaxial control, and in (D), the second shell has formed after an edge bypass has occurred. The production of fullerene is hypothesized to be the result of statistical closure at stage (C).

With the permission of Nature Publishing Group, Mojica M, Alonso JA, Méndez F. Synthesis of fullerenes. J Phys Org Chem. 2013;26(7):526–539 reprint the following from H. W. Kroto and K. McKay's 1988 issue of Nature: 331–328.

is closed with the proper arrangement of pentagons. Iijima [33] used high-resolution electron microscopy to discover embryos that did not close and continued to develop into quasi-spiral soot particles (Fig. 5.6).

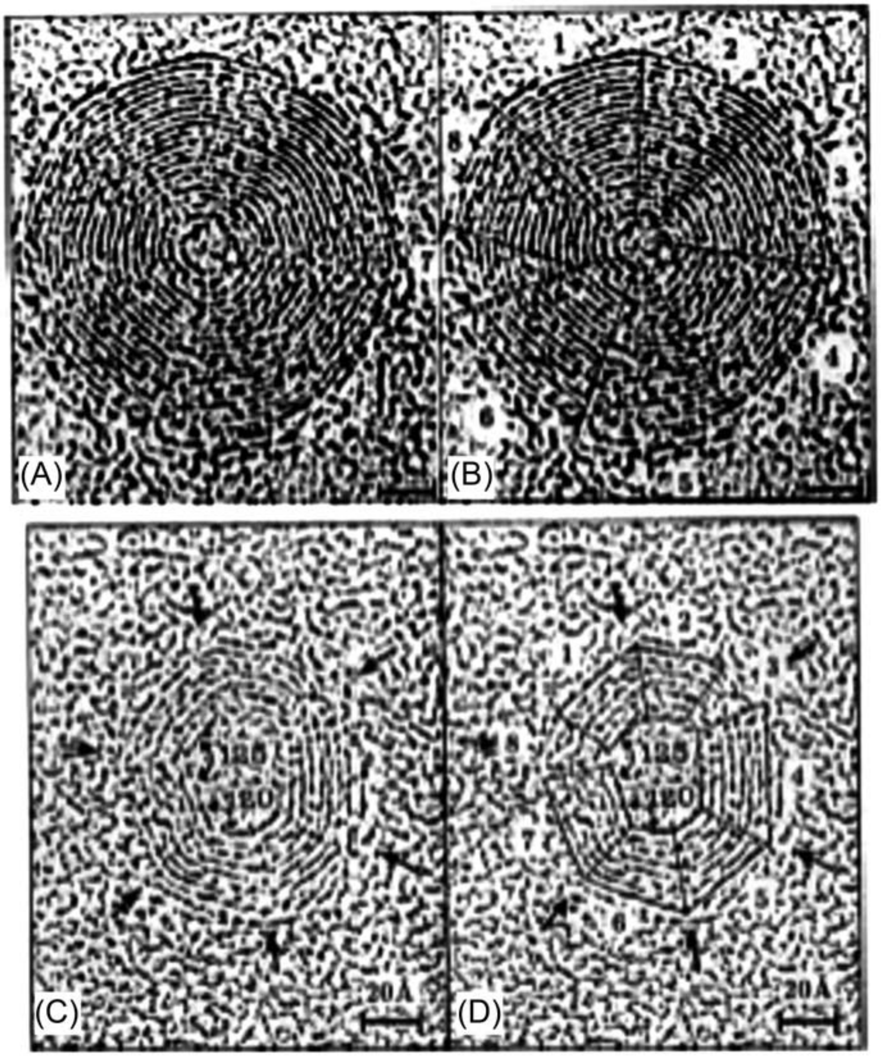


FIGURE 5.6

Images of particles captured by Iijima's high-resolution electron microscope. A polyhedral concentric shell structure may be seen in the photos. The outline is shown in more detail below.

With the permission of the American Association for the Advancement of Science, Mojica et al. (2013) reprint the following article from H. Kroto's 1988 issue of Science: 242, page 1139, Mojica M, Alonso JA, Méndez F. Synthesis of fullerenes. J Phys Org Chem. 2013;26(7):526–539.

There are, however, data that challenge this theory. In addition, the fullerene creation that takes place in an expanding He jet according to the icospiral model takes 10−4 seconds to complete, whereas the experimental work that was done to conclude that fullerenes are generated on a significantly shorter timescale of 10−12 to 10−9 seconds [34] suggests that fullerenes are created on a much more rapid timescale.

5.3 Applications of fullerenes in food science and safety

The fact that NOLFs, also known as nanocarbon onion-like fullerene, are compatible with the cells and tissues of animals led to their use in agricultural settings. It has been demonstrated that the presence of nanocarbon fullerenes in plants considerably increases the amount of fruit that the plant produces [35]. Additionally, the capacity of NOLFs to retain water is enhanced, which contributes to ongoing productivity. According to Jain et al. [36], nanocarbon fullerenes have antifungal effects in plants and assist in the elimination or amelioration of various plant diseases [36]. In plants and animals, materials containing fullerene have been introduced, which has led to an increase in the biomass of such creatures. It has been demonstrated that the use of fullerene materials can boost the output of tomatoes as well as a variety of citrus fruits. These findings have given researchers new insights into the rapid growth of plants and, by extension, animals, which can be used to improve agricultural productivity and production. According to Zhao et al. [37], the deployment of these technologies in horticulture has led to an increase in revenue in this sector [37].

5.3.1 Food toxin detection

The first synthetic allotrope of carbon, known as fullerene, was discovered in 1985 by H. W. Kroto and colleagues (who later won the Nobel Prize in Chemistry for their work) [3]. This marked the beginning of the field of carbon nanomaterials (CNMs). The vast majority of fullerenes are nonbiodegradable compounds, the potential toxicity of which has not been completely researched up to this point. Concerns about biosafety and the environment have been stoked by the rising demand for and manufacturing of fullerenes in large quantities. Testing for toxicity in living organisms, often known as in vivo testing, offers entire models for predicting the responses of biological systems. The results of these in vivo study models include a wide range of cellular, anatomical, and physiological aspects. In addition, the fact that they are relatively small in size, have a relatively rapid development rate, and a relatively brief life cycle makes them appealing for the purpose of studying the toxicological effects of nanomaterials. At different levels of these in vivo model systems, several ways of toxicity evaluations have been established. Some examples of these methods include morphological alterations measured under a microscope, cellular alterations, altered gene or protein expression, biochemical analyses, and behavioral alterations [38].

CNMs' usefulness and high electrochemical qualities make it possible that they might be used to selectively immobilize biomolecules for the detection of toxic substances in food. Electrochemical detection of dietary contaminants relies heavily on CNMs, as seen above [38].

The use of carbon nanoparticles in biosensors is a relatively new development in the field. Due to their superior sensitivity and selectivity, ease of use, low cost, portability, and downsizing in some situations, biosensors have emerged as a dependable and promising alternative analysis tool to those of classical methods [39]. A biosensor is a device that uses a transducer of choice to detect a physiochemical change brought on by a predetermined interaction between a target analyte and a biological element. Point-of-care diagnostics and environmental monitoring, including for food hazards, have both seen a rise in interest in biosensing devices during the past decade. Biosensors typically consist of three main parts: a biorecognitionelement (DNA, enzyme, antibody, etc.) for recognizing an analyte (also called a bioreceptor), an immobilization matrix and self-assembled monolayers [40] for immobilizing a biomolecule, and a transducer unit for transforming the product of a biochemical reaction into an easily interpretable signal.

It might take anywhere from several hours to many days for conventional culture, immunological, or molecular approaches to detect infections and spoilage organisms in food. Recently, "nano-biosensors" have emerged as a result of the integration of nanotechnology with existing biosensing techniques; these sensors exhibit fast response times alongside high sensitivities [5,41,42].

Biosensors for evaluating food quality and safety are increasingly being built on top of aptamers originally developed for toxin detection [43]. The fascinating features of carbon nanomaterials including carbon nanotubes (CNTs), graphene quantum dots (GQDs), graphene, and fullerenes are attracting a lot of attention [44] (Figs. 5.7 and 5.8).

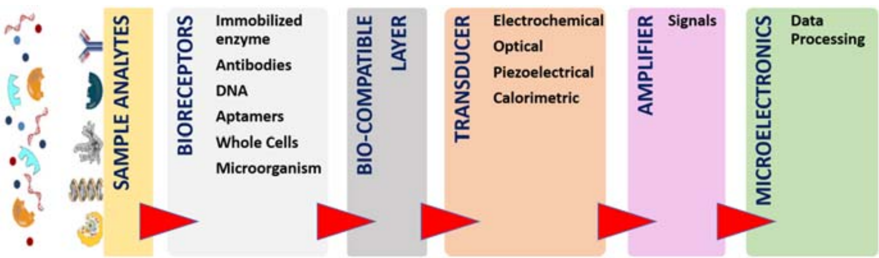


FIGURE 5.7

Schematic presentation of biosensors.

Malhotra BD, Srivastava S, Ali MA, Singh C. Nanomaterial-based biosensors for food toxin detection. Appl Biochem Biotechnol. 2014;174(3):880–896.

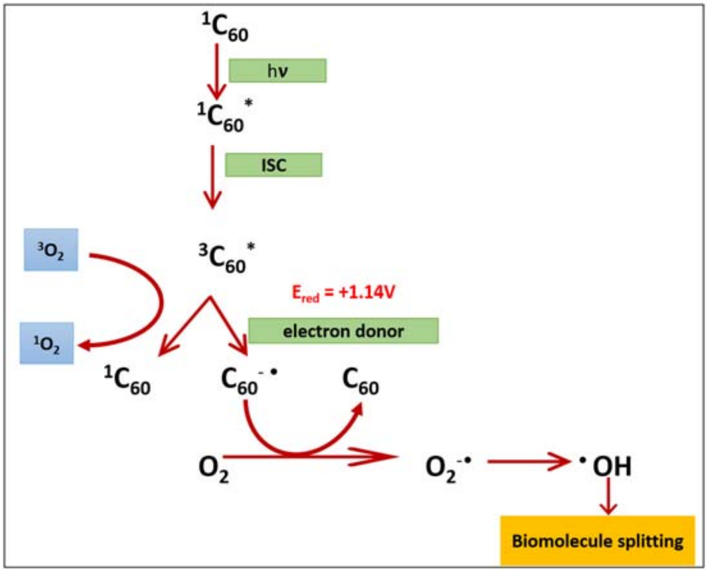


FIGURE 5.8

Photoexcitation of fullerene generates singlet oxygen, as depicted in this schematic. Inter System Crossing (ISC). In the presence of an electron donor, $^1C_{60}$ and $^3C_{60}$, both of which are good electron acceptors, are reduced to $C_{60}^{\ddot{\imath}\,-}$. This causes singlet oxygen radicals to be produced.

5.3.2 Shelf life extension

Agriculture and the food sciences are being more integrated with nanotechnology. Preservative sprays and other food-related applications of nanomaterials are already on the market [45]. For instance, nanocoating sprays are used to preserve fruits and vegetables, and packaging material containing silicate nanoparticles has been produced to limit the oxygen penetration and lengthen food shelf life [46]. Nanoparticles and nanoemulsions are being used to improve the quality of foods in a variety of ways, including making them easier to pour, boosting their flavor, and providing more efficient nutrition delivery [47]. Nanomaterials based on carbon (carbon black, fullerenes, carbon nanotubes), silver, silicon, tin oxide, zinc oxide, and cerium oxide are among the most popular on the market today [48].

5.3.3 Agricultural improvement

The use of nanomaterials (NMs) has gradually expanded in the agricultural sector due to the unique size of NMs, their capacity for absorption/penetration and translocation within cells, and the low cost of formulation of NMs. An astounding success of nanotechnology in the agricultural industry has been the discovery that fullerene, C_{60}, and carbon nanotubes (CNTs) can boost the water-retaining capacity, biomass, and fruit output in plants. This is an example of the use of nanotechnology. There was also a roughly 200% rise in tomato output after CNTs were applied. Carbon-based NMs, both functionalized and nonfunctionalized, have the potential to boost crop yields by improving a plant's capacity for water absorption and retention within its cells, boosting the plant's physiological and metabolic activities, and also by fostering the growth of cellular defense mechanisms [49].

Proteins, surfactants, polysaccharides, lipids, phospholipids, and fatty acids are only some of the natural food-grade macromolecules that make up nanoparticles. Different combinations of these food-grade substances can generate composite nanoparticles, such as lipid core with a protein (also known as "nanoemulsions") or lipid droplets inserted in the biopolymer microspheres [50]. These food-grade nanoparticles can assist in improving the efficiency, utilization, and stability of bioactive food ingredients by encapsulating, protecting, and releasing the bioactive food constituents [51]. The nanoformulation approach is used to create nanonutraceuticals, which combine nutrition and pharmaceuticals and include things such as dietary supplements, bioactive chemicals, functional foods, and herbal products [52]. Various strategies were used to administer the nutraceuticals. Liposomes, cubosomes, microemulsions, solid lipid nanoparticles (SLNs), biopolymeric nanoparticles, nanosensors, monolayers, microgels, and fibers are just some of the vehicles used to transport nanotubes, nanofibers, fullerenes, nanosheets, and nanowhiskers [53].

5.3.4 Polymer/fullerene nanocomposites coating for corrosion resistance intended for

5.3.4.1 Biomedical applications

Metal surfaces can be protected against corrosion by applying a corrosion coating [54–56]. Coatings' resistance to corrosion is affected by many variables [57,58]. Polymers with embedded carbon or metal nanoparticles improve coating performance even more [59–61]. The resulting high-performance polymer/nanocarbon-nanocomposite coatings are lightweight, cheap, and highly processable [62–64]. It has also been found that coatings made of polymer nanocomposite materials that contain fullerenes can improve corrosion resistance [65–67]. A polymer/nanocarbon nanocomposite's anticorrosion process is predicated on the development of a homogeneous covering, the dispersion of nanoparticles, and the generation of diffusion routes for corrosive species [68–70]. Fullerenes, like other nanocarbons, offer excellent anticorrosion properties [71]. When interacting with polymers, fullerenes can form electrostatic interactions, π-π interactions, van der Waals interactions, and hydrogen bonds. These bonds aid in charge transfer, which in turn improves corrosion resistance [72]. Different polymers have been filled with fullerenes. Anticorrosion coatings made from polyaniline, one form of conducting polymer, have seen widespread use in recent years [73,74].

Polyaniline's low level of toxicity, hydrophilicity, excellent electrical conductivity, biocompatibility, and in vivo stability make it useful in biomedical applications. Despite its degradability and modest processing capabilities, polyaniline has few practical applications. Biosensors, medication delivery, antimicrobials, and tissue regeneration/engineering are just few of the biological applications of nanomaterials that Zare et al. [75] investigated. Epoxy coatings that resist corrosion have been documented as one sort of thermo set [76–78]. In this case, epoxy/nanocarbon nanomaterials have excellent chemical/mechanical/heat stability [79,80] in addition to good hydrophobicity, contact angle, and moisture-resistance qualities. Epoxy nanocomposites' anticorrosion characteristics have been studied extensively [81–83]. Composites of thermoplastic polymers and C_{60}/C_{70} molecules have also been developed [84,85]. Nanomaterials made of polyurethane and fullerene were investigated for their corrosion-resistant properties [86]. As another example, poly (methyl methacrylate)/fullerene nanocomposites were employed as a corrosion barrier [87,88].

Research on the use of fullerene nanoparticles with anticorrosion properties in biomedical implants is ongoing. Anticorrosion bioimplants made from fullerenes have shown the most promise [89,90]. Effective use of fullerenes in magnesium-based metal implants has been demonstrated. Sodium dodecyl sulfate was utilized as a surfactant by Samadianfard et al. [91] to stabilize fullerene materials before they were incorporated into nanocomposites. The Mg implants had an anticorrosion coating applied to them using the sol–gel technique. In order to evaluate the resistance of the implants against corrosion, electrochemical impedance spectroscopy was carried out in a solution containing 3.5 wt% NaCl. The corrosion tests concluded with scanning electron microscopy and energy-dispersive X-ray spectroscopy, which showed that the surface of the implants made of a polymer/fullerene nanomaterial was the least damaged by the corrosion. The potential of fullerene nanoparticles for an orthopedic magnesium (Mg)-based bionanocomposite was later examined by Jayasathyakawin et al. [92]. The cytocompatibility of bioimplants covered in nanomaterials was investigated by Wang and colleagues [93]. Bioimplants were tested for their resistance to corrosion and osteoporosis. Furthermore, Pourhashem et al. [94] investigated the durability of corrosion-resistant fullerene nanostructures in biological systems. Biocompatibility and biostability were improved when Mg metal was covered with anticorrosion fullerene nanoparticles. Therefore, bioimplants have shown to be one of the most fruitful areas of use for anticorrosion fullerene-based materials in the field of biomedicine.

5.4 Biomedical applications of fullerenes

Fullerenes can be altered indefinitely and are both solid and hollow. Water-soluble forms are not absorbed when taken orally, but they are rapidly disseminated to different tissues after being injected intravenously. The kidneys flush them out unaltered [95]. Studies on the acute toxicity of water-soluble fullerenes have yielded surprisingly positive results [96]. These intriguing features point to a promising future for fullerenes as therapeutic agents in the fields of biology and medicinal chemistry.

However, there is a huge obstacle in the way of this possibility, and that obstacle is the intrinsic repulsion that fullerenes have toward water. In order to circumvent this constraint, a variety of other approaches are now being developed. These include the synthesis of fullerene derivatives with a changed solubility profile, the encapsulation of C_{60} in cyclodextrins [97], or in calixarenes [98], as well as preparations for water suspension [99].

Several fullerene analogs have been successfully synthesized. Numerous fullerene-related patents have been filed, and the corresponding database is expanding rapidly. As fullerenes and their derivatives showed promising preliminary activity in a variety of medical fields, researchers are devoting a great deal of time and energy to learning more about them.

5.4.1 Diagnostic applications

The fullerenes known as endohedral metalofullerenes are those that have a metal ion trapped inside the fullerene cage. In the field of diagnosis, these have demonstrated promising usefulness. As an illustration, water-soluble forms such as $M@C_{82}(OH)_{30}$ are currently being utilized as contrast agents for MRI ($M = Gd^{3+}$) [100], X-ray ($M = Ho^{3+}$) [101], and radiopharmaceuticals ($M = 166Ho^{3+}$ and $170Tm^{2+}$) [102,103]. One of these compounds, known as $166Ho^{3+}@C_{82}(OH)_{30}$, has been the subject of a significant amount of research as a radioactive tracer for the purpose of visualizing sick organs and destroying cancerous tumors. The radioactive metal is held securely within the carbon shell, which is extremely stable and resistant to being metabolized by the body. It has been discovered that metallofullerenes are nontoxic, and because they remain in the body for around 1 hour, imaging of the circulatory system can be performed with them.

5.4.2 Anti-HIV activity

It has been demonstrated that the protease enzyme that is unique to HIV-1 can serve as a useful target for antiviral treatment. It is possible to think of the active site of this enzyme as an open-ended cylinder lined almost entirely by hydrophobic amino acids, with the exception of two catalytic aspartic acids. This is a very general description. It was suggested by Wudl and colleagues that because the C_{60} molecule has a radius that is nearly the same as the cylinder that characterizes the active site of HIV-P, there is the potential for a powerful hydrophobic contact between C_{60} derivatives and the surfaces of the active site. The molecular modeling studies and experimental findings that were carried out by Simon H. Friedman and colleagues in 1993 indicated that the presence of C_{60} inhibited

HIV-P replication [104]. The effectiveness of fullerene derivatives in inhibiting HIV-1 and HIV-2 replication was demonstrated by virus inactivation experiments [105,106]. In acute and chronically infected human lymphocytes, it was discovered that a water-soluble derivative was active against HIV-1 and HIV-2 (with an EC50 of roughly 6 M). At the same time, it was found to be noncytotoxic up to 100 M in peripheral mononuclear cells as well as H9, Vero, and CEM cells [107].

As the empirically determined binding constant for HIV-P contact was not very high [104], research into structural optimization of C_{60} derivatives for HIV-P interaction was undertaken. On the basis of this observation, a number of writers have developed ideal inhibitors consisting of two ammonium groups directly connected to C_{60} at a distance of 5.5 or 5.1. Fitting well into the HIV-P cavity and able to interact with aspartic acid carboxylic residues, these derivatives were the subject of molecular modeling investigations [108].

5.4.3 DNA photocleavage

It was discovered that a carboxylic acid derivative of fullerene that is soluble in water is cytotoxic when exposed to sunlight. C_{60} carboxylic acid was first treated with cultivated cells for 3 days in the first experiment. There was no evidence of any kind of life. However, the chemical was lethal to cells when exposed to weak visible light. Cleavage of DNA was later found to be the mechanism by which C_{60} derivatives caused cytotoxicity [108]. As fullerenes are so simple to photoexcite [109], photodynamic drugs based on fullerenes are currently being researched for the treatment of cancer. Many different types of fullerene conjugates are being studied for their potential anticancer effects. These conjugates feature units with biological affinities for nucleic acids or proteins. In order to boost cytotoxicity and sequence selectivity, researchers have produced conjugate between C_{60} and specific compounds that interact with nucleic acids, such as acridine47 or complementary oligonucleotide [109,110]. Although sequence selectivity was low, DNA cleavage was discovered to take place at a guanine residue [110]. A C_{60}-PEG conjugate, when exposed to light, induces tumor necrosis strongly without damaging the overlying normal tissue, resulting in complete cure at a C_{60}-PEG dose of 0.424 mg/kg and irradiation power of 1011 J/m^2 [111]. After 2 weeks of exposure to UV radiation, the cytotoxicity of dendritic C_{60} monoadduct and malonic acid C_{60} trisadduct on Jurkat cells was studied, and the results showed a reduction in cell number to around 19% [112]

5.4.4 Free radical scavenger

Amyotrophic lateral sclerosis (ALS), also known as Lou Gehrig's disease, and other forms of neurodegeneration in the developing brain have been related to free radicals. Because of their unusual cage structure and large number of conjugated double bonds [30] in the core, fullerene compounds are highly reactive toward free radicals and can interact with biomolecules. For instance, Buckminster fullerenes can incorporate several radicals into a single molecule; one C_{60} sphere has been shown to incorporate as many as 34 methyl radicals. As a result, they are called a "free radical sponge" [113]. Several fullerene derivatives have been developed, nevertheless, and these are said to have a protective effect in a number of systems, as well as an improved solubility profile compared with the native fullerenes. In vitro and in vivo studies have demonstrated that fullerenol, a water-soluble C_{60} derivative, can neutralize free radicals. Hydrogen peroxide inhibits population spikes in the rat hippocampus, while fullerenol prevents this effect [114,115].

Carboxy-fullerene is another water-soluble derivative of fullerene that has effective neuroprotective antioxidant activity in vitro and in vivo (hundreds of times more powerful than vitamin E) and has been shown to prevent apoptotic injury evoked by *N*-methyl D-aspartate (NMDA) without interfering with NMDA-induced Ca^{2+} influx in cortical cell cultures [116]. The protective effect of fullerene derivatives as a free radical scavenger has been shown in a number of different systems. These include a decrease in ischemia reperfusion intestine injury [117], protection of various cell types from apoptosis, a lower concentration of free radicals in organ perfusate, and a neuroprotective effect [116,118–121]. The fact that both water- and lipid-soluble derivatives of fullerene are possible, in addition to the positive results seen in pretoxicity studies, greatly increases the usefulness of fullerene derivatives as antioxidants in health and personal care products such as skin creams, burn creams, and nutritional supplements.

5.4.5 Antimicrobial activity

Fullerenes were thought to contain antibacterial activity based on the notion that C_{60} might create membrane disruption by inserting itself into phospholipid bilayers [122]. This led to the expectation that fullerenes would possess antibacterial activity. The disruption of the membrane, which results in altered permeability, ultimately results in the release of metabolites and the death of the cell. For instance, fulleropyrollidines with monomethoxytriethylene glycol (mTEG) substitutions completely inhibited Mycobacterium avium at a dose of 260 μg/mL and *Mycobacterium tuberculosis* at a dose of $\cong$50 μg/mL [123]. It has been suggested that the presence of a carbon cage destabilizes the tubercular cell wall by intercalating in the hydrophobic region of the structure. This is a viable explanation for the antitubercular activity. The affinity of carbon cage for the hydrophobic constituents of Mycobacterium cell wall, that is, ceramide, has been further proven by the intraperitoneal injection of mTEG fullerene derivative that was given to mice. Ceramide is the hydrophobic component of the Mycobacterium cell wall. According to Tsao and colleagues' 2001 research, it was discovered that the derivative was deposited on Tyson's gland, which is another tissue that is abundant in ceramide [122]. Carboxyfullerenes, which are another fullerene derivative, have been subjected to extensive research for their potential antimicrobial properties.

Carboxyfullerenes were discovered to decrease *Escherichia coli*—induced meningitis; however, they did not do so by directly inhibiting *E. coli*; rather, they inhibited the disease by lowering the damage produced by invading neutrophils on the blood—brain barrier. The growth of Streptococcus pyrogens strain A-20 was shown to be suppressed by the carboxyfullerenes (MIC 5—50 mg/L) according to Tsao et al. [122] findings. Because these derivatives had varied effects on Gram + ve and Gram − ve bacteria, additional research led to the discovery that carboxyfullerenes can insert themselves into the cell wall of Gram + ve cocci, causing the cell wall structure to become disrupted and ultimately leading to the death of the Gram + ve bacteria. According to Tsao et al. [122], fullerenes are unable to penetrate the cell wall of Gram − ve organisms because these species have an outer membrane that is composed of lipoproteins, lipopolysaccharides, and phospholipids [122]. According to this evidence, carboxyfullerenes have the potential to become novel antimicrobial drugs that target Gram + ve cocci (Fig. 5.9).

5.4.6 Osteoporosis

The medications that are now utilized for the treatment of osteoporosis and other bone problems are fluoride anions and biphosphonate compounds. However, the

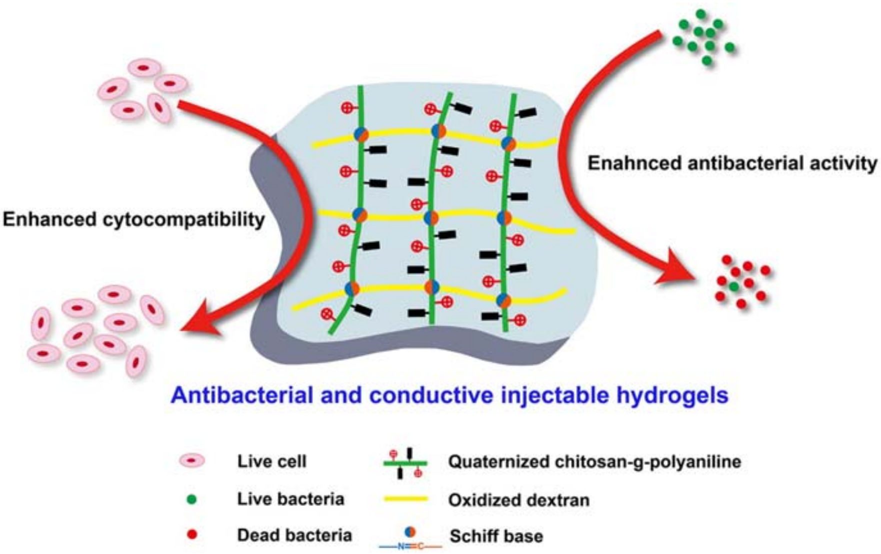


FIGURE 5.9

Antibacterial activity of a polyaniline nanomaterial [124,125].

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former cannot be absorbed through the digestive tract, while the latter are highly poisonous. The preferential localization of fullerene derivatives in bones is being exploited for its potential medical benefits. Accordingly, polyfluorobiphosphonated fullerene derivatives are currently in the process of being developed as a bimodal medication for the treatment of osteoporosis [126].

However, fullerenes must be measured in terms of dosage and serum levels using sensitive and straightforward immunological protocols in order to be used as biological or pharmacological agents. This, in turn, necessitates the availability of fullerene-specific antibodies. Because of this need, the question of whether or not these carbon-based spheres can stimulate the immune system to generate targeted antibodies was raised. The immune system is diverse enough to recognize and process fullerenes as protein conjugates, as demonstrated by the fact that immunizing mice with a water-soluble C_{60} fullerene derivative conjugated to bovine thyroglobulin resulted in a population of fullerene-specific antibodies of the IgGisotype [127]. The light and heavy chain sequences of a monoclonal fullerene-specific antibody have been disclosed [128]. These results add weight to the argument that fullerenes have real-world applications as therapeutics, diagnostics, and imaging vectors.

5.4.7 Fullerenes in drug and gene therapy

Due to the cell membrane, the endosomal membrane, and the nuclear membrane, transporting any substance into the nucleus of an intact cell is extremely difficult. Nanoparticles are just one type of carrier that has been developed to facilitate transfer. Fullerenes are a type of inorganic nanoparticles with a size of less than 1 nm [129]. The fullerene core is highly hydrophobic, but by adding hydrophobic moieties, fullerenes can become water-soluble and contain medicines and genes for cellular delivery. Fullerene derivatives can enter the cells and bind to the mitochondria. It has been revealed that Amphotericin B can be targeted to cells using a variety of carbon nanotubes with varying functions. Doxorubicin combined with nanotubes improved the drug’s ability to enter the cells. Carbon nanotubes, being nanosized, have a use in the production of tablets as lubricants or glidants [129].

5.4.8 Pristine C_{60} fullerene nanoparticles ameliorate hyperglycemia-induced disturbances via modulation of apoptosis and autophagy flux

Neuropathy, memory loss, and cognitive impairment are all consequences of diabetes mellitus, a common metabolic condition. Despite decades of research into the effects of diabetes, we still lack effective therapeutic methods for neuroprotection. Cell viability in brain tissue may decrease due to hyperglycemia-induced disruptions in planned cell death. Depending on their composition and surface properties, certain nanomaterials can either kill or sustain cells. C_{60} fullerene in its purest form is a nanomaterial with antioxidant and cytoprotective capabilities that is safe for human use [130]. C_{60} nanoparticles have been shown to have a cytoprotective effect in diabetic individuals; however, the underlying molecular mechanism is still unclear. The study carried out by the Demir and coworker [130] set out to clarify the potential pathways by which C_{60} fullerene protects oxidative stress impairment in diabetes mellitus by investigating its effects on apoptosis and autophagy [130]. C_{60} fullerene, which was derived from olive oil, was tested for its effects on the hippocampus of STZ-induced diabetic rats. The brains of STZ-diabetic rats showed upregulation of Caspase-3, Beclin-1, and oxidative stress indices and downregulation of Bcl-2. After 12 weeks of treatment with C_{60} fullerene, oxidative stress, hyperglycemia-induced apoptotic abnormalities, and autophagy fux were all reduced by changes in the levels of the proteins Caspase-3, Bcl-2, Beclin-1, and LC3I/II. C_{60} fullerene also reduced the LC3I/II ratio and the autophagy flux to keep it from being too high. In contrast, in nondiabetic individuals, pure C_{60} fullerene did not have any moderating effect on any of the apoptotic or autophagy markers tested. Therefore, C_{60} fullerene derived from oil has a cytoprotective effect in hippocampus cells subjected to hyperglycemia stress. Using their antioxidant, antiapoptotic, and autophagy-enhancing properties, Demir and coworkers confirm in their study that pure C_{60} fullerene nanoparticles can shield hippocampus cells from hyperglycemic stress. Hippocampal functional disruptions may be avoided thanks to C_{60} fullerene's ability to regulate autophagy via BCL-2/Beclin-1 reciprocal expression [130].

5.5 Consumer exposure

As fullerenes aren't widely used in consumer goods, cosmetics are likely to be the major way people are exposed to them [131]. For more information on the antioxidant characteristics of fullerenes, see Table 5.1. Fullerenes are utilized in a variety of cosmetic goods, including antiaging treatments and sun creams. Vitamin C_{60} BioResearch Corporation, a manufacturer of fullerenes used in cosmetics, describes their product on their website as "fullerene-containing vegetable squalane" or "polyvinylpyrrolidone wrapped fullerenes." CosIng, a database maintained by the European Commission, identifies fullerenes and hydroxyfullerenes as acceptable substances for use in cosmetics for their antibacterial and skin-conditioning properties, as specified in the "Cosmetics Directive" (76/768/EEC).

In recent years, fullerenes have also garnered a lot of interest as a potential treatment for neurodegenerative disorders and cancer, both of which have been linked to reactive oxygen species (ROS) or radical formations as their underlying mechanism [136–138].

Table 5.1 Fullerene use and its function in cosmetic products.

Application	Function	Fullerene type	References
Skin rejuvenation (antiaging, antiwrinkle) skin care products	Skin nutrient, antioxidant, free radical scavenger	C_{60} and derivates: fullerene-containing vegetable squalane polyvinylpyrrolidone wrapped fullerenes hydroxyfullerenes	[131]
Skin whitening agent	Inhibition of melanogenesis	Radical sponge_ (polyvinylpyrrolidone wrapped fullerene)	[132]
Sun creams	Protection of oxidative skin damage caused by UV(A) and UV(B)	Fullerenes and derivates	[133]
Makeup	Fillers and pigments	Not specified	[131]
Hair care products	Potentiate hair growth	Fullerene derivatives	[134]
Antimicrobial	Inhibition of microbial cell growth	Fullerenes and hydroxylated derivatives	[135]

As a result of its high stability, high repulsion, and low weight, fullerenes find use in sporting products such as tennis rackets. It is anticipated that fullerenes will be encapsulated within a matrix in such items, and that their exposure will be negligible or nonexistent under normal use conditions (e.g., wear and tear). Unfortunately, we have been unable to locate data that quantify exposure due to such consumer products.

Because of this, dermal exposure, even over a longer length of time, might be predicted from the use in cosmetics, and the skin is thus considered the primary exposure route for customers. It is uncommon for the amounts of fullerenes in beauty products to be specified. Concentrations of fullerenes in liposomes in such products typically range from 0.2% to 0.5% [131,139]. Although the concentration of fullerene in skin cream is unlikely to be precisely known, it can be safely assumed to be lower than 0.5%, given the wide range of liposome concentrations that may be present.

5.6 Fullerenes as a human health hazard

Fullerenes' toxicity and toxicokinetics were examined in depth by Johnston et al. [140]. This chapter expands on previous studies by explaining and extracting data useful for risk assessment, and it features updated, cutting-edge information. Research on toxicokinetics and toxicity yielded the results summarized in Table 5.2.

Table 5.2 Summary of hazard assessment of fullerenes.

Absorption	Inhalation	No/limited systemic absorption from lung, fullerenes are phagocytosed by macrophages	[141]
	Oral	Limited absorption (<3%)	[96,142]
	Dermal	No penetration into dermis; solvents can modulate fullerene penetration deep into the stratum corneum	[143,144]
Distribution	Pulmonary exposure	Limited/no translocation to liver, brain, kidney, spleen	[145]
	Intraperitoneal/ intravenous	Transport to and accumulation mainly in liver, but also in kidney, lung, spleen, heart and brain	[96]
Elimination	Oral, intraperitoneal	Via feces and urine, probably depending on water solubility	[96,146]
Acute/repeated dose toxicity	Oral exposure	Very low acute toxicity; no data on repeated exposure	[127,146]
	Inhalation	Low acute and subchronic toxicity	[96]
	Dermal exposure	Low acute toxicity, no data on chronic exposure	[135]
Irritation		Highly purified fullerenes and fullerene soot were not irritating to skin and eye in animals and in human studies	[135]
Sensitization		Highly purified fullerenes and fullerene soot were not sensitizing in animals and in human studies	[135]
Mutagenicity		Indirect genotoxic effects via formation of ROS possible	[147]
Carcinogenicity		Antiinflammatory and antitumor effects of certain fullerene types reported; not carcinogenic after intraperitoneal exposure for 25 weeks; no cancer assay viaphysiologically relevant routes available	[148]
Reproductive/ developmental toxicity	Inhalation dermal exposure	Developmental effects at high doses in mice; relevance for human exposure situationsis questionable.	[149]

5.6.1 Absorption, metabolization, distribution, and elimination of toxins

Research on the toxicokinetics of fullerenes after inhalation, ingestion, or skin contact is crucial for determining potential target organs for fullerenes' toxicity. Several barriers prevent subsequent targets from taking in radiation that has been absorbed at the primary site of exposure. However, fullerenes can become systemically accessible and exert their harmful effects throughout the body if they are able to circumvent these barriers.

5.6.1.1 Absorption

Oral—Oral administration of radiolabeled ^{14}C fullerene derivatives (trimethylenemethane) to rats and mice showed that the majority (97%) were eliminated in the feces within 48 hours, despite the fact that the animals were exposed to the compound for up to 160 hours. Some fullerenes were found in small concentrations in the urine, indicating that they made it past the intestinal wall [96]. Folkmann et al. also suggested that fullerenes are absorbed after oral exposure because oxidative damage was seen in a dose-dependent manner in the liver and lungs after oral treatment by gavage [142]. The significance of these results is unclear because the same effect was shown when using the solvent maize oil, and fullerenes' presence in these organs was not established.

Inhalation—Baker et al. found that fullerenes, both nano and microparticulate forms, did not appear in inhaled rats' blood, suggesting that they do not cross the blood−brain barrier. Exposure to C_{60} fullerene nanoparticles resulted in pulmonary deposition fractions (14.1%) higher than those of microparticles (9.3%). The shorter half-life of 26 days may be due to the same elimination processes in the lungs. After 130 and 145 days, steady-state lung loads were not predicted to be reached in rats [141].

It has been proven that specific nanoparticles can be transported to different parts of the brain via the olfactory nerve. Fullerenes have been shown to cause oxidative stress in the brains of fish after exposure, which may indicate that they are transported there [150]. However, as no reports of fullerene translocation have come from investigations involving mammals, it is unclear whether these results are applicable to human exposure circumstances. After intratracheal instillation (3.3 mg/kg) and inhalation exposure (0.12 mg/m^3) in rats, Shinohara et al. found no transfer of C_{60} particles to organs other than the lung, indicating that fullerene absorption is insignificant [145].

Fullerene nanoparticles, on the other hand, were hypothesized to cross the air−blood barrier (ABB) via diffusion and caveolae-mediated pinocytosis, leading to rapid translocation into the circulatory system and subsequent distribution to various organs and tissues by Naota et al. [151]. Suspension-induced edema in the lung may have altered the physiological transportation mechanism in the lung and into the systemic circulation, which could have contributed to the observed translocation of particles. As a result, it's possible that the results obtained under these conditions aren't applicable to inhalation exposure.

Dermal—Primitive fullerene nanoparticles can permeate deeply into the stratum corneum and be modulated by solvent, as demonstrated in vivo (tape stripping and skin tissue biopsies in weanling pigs) and in vitro (stratum corneum the absorption and flow through diffusion cell experiments). Hill Top Chambers were used to apply a 500 lL solution containing 200 lg/mL C_{60} in different solvents to specific skin areas for 24 hours, with daily dosing with freshly produced solutions over the course of 4 days. Toluene, cyclohexane, and chloroform all facilitated C_{60} uptake into the stratum corneum, but mineral oil had a little effect. After

1 hour, the stratum corneum's rapidly absorbing superficial layers (stratum disjunctum) slowed down, perhaps due to a slow transportation process through the lipid bilayers. The scientists stated that the risk assessment for C_{60} in industrial organic solvents should take into account solvent effects because they are critical in the skin penetration of fullerenes.

Kato et al. studied skin permeability of C_{60} dissolved in LF-SQ for 24 hours using a modified Bronaugh's diffusion chamber [144]. They found that low concentrations of C_{60} were undetectable on the epidermis and dermis. Human skin biopsies showed that C_{60} can penetrate the epidermis at doses as high as 223 ppm but not the dermis. This suggests that systemic toxicity is not an issue when C_{60} is dissolved in LF-SQ [152].

Distribution, metabolism, and elimination—For this reason, it is likely that nothing is known about the distribution of fullerenes after their inhalation, oral, or cutaneous absorption. Under situations of lung particle overload accompanied by an inflammatory state, it has been demonstrated that some nanoparticles can be translocated to secondary organs from the respiratory tract via uptake into pulmonary lymphatics and blood circulation [153].

Recent research has shown that fullerenes, including C_{60}, are not metabolized due to their low pulmonary clearance and the link between C_{60} and 13C distribution [145]. Alveolar macrophages in the lungs ingest fullerenes, which can lead to oxidative or inflammatory processes [154]. Fullerenes can accumulate in the liver, kidney, and spleen after intraperitoneal injection. Keratinocytes, epithelial cells, and eye lens cells are some cell types that internalize fullerenes in vitro, often with oxidative and fatal repercussions. Derivatized fullerenes and C_{60}/C_{70} fullerene mixtures have been excreted in the feces after intravenous and oral administration to rats, but the excretion of derivatized fullerenes is slow [155,156].

Fullerenes have a tendency to remain at the deposition location, notably within the lungs and gut [157]. They can be removed through alveolar macrophages, the mucociliary escalator, or through the feces and urine [127,158,159]. Surface alterations, surface coatings, and skin characteristics all play a role in determining the extent of fullerene absorption through the skin. Further research is needed to confirm whether fullerenes can be absorbed through relevant exposure routes and reach organs that are remote from the deposition site. Surface alterations can affect toxicokinetics, and information on the toxicokinetics of fullerenes is essential for understanding the effects of exposure, particularly after intraperitoneal and intravenous application. Radioisotope or fluorescence labeling is suggested to facilitate accurate identification of fullerenes [96,146].

5.7 Acute and repeated dose toxicity

Since there aren't many well-accepted acute or repeated dosage toxicity tests for fullerenes, the few that do exist are summarized here.

5.7.1 Oral exposure

After 14 days of observation following oral administration of 2000 mg/kg fullerite (a combination of C_{60} and C_{70}), no toxicity in terms of mortality or other behavioral or body weight indicators was observed in rats [146]. Chen et al. found that after a single oral dose of 2500 mg/kg, polyalkylsulfonated (water soluble) C_{60} had no effects in rats; hence, it was concluded that it was not acutely hazardous [160]. The results of these two investigations reveal that the acute No-observed adverse-effect-levels (NOAEL) for fullerite (a combination of C_{60} and C_{70}) and polyalkylsufonated (water soluble) C_{60} are 2000 and 2500 mg/kg bw, respectively. The true acute oral NOAEL is probably higher than what was reported in either study because only one dose was examined. In conclusion, fullerenes have low acute oral toxicity; however, data on chronic oral exposure are lacking.

5.7.2 Pulmonary/inhalation exposure

The greatest cause for concern with (airborne) nanoparticles is their inhalation. Deposition of individual NP in the respiratory tract, where they can have local impacts, is dependent on the particle size (aerodynamic diameter).

Studies have revealed that nanometric particles, which are extremely small in size, can cause more inflammation and tumor growth than bigger particles of the same mass. Although it has been demonstrated that some pulmonary nanoparticles are distributed to other organs, no broad conclusions can be drawn from these studies [153]. Multiple studies have shown that many nanoparticles cause inflammation in the lungs [161], although this is not always the case with fullerenes. Summary of inhalation and intratracheal instillation experiments' findings.

5.7.3 Inhalation

Fischer 344 rats were exposed to fullerenes via nasal inhalation at 2.22 mg/m^3 (nanoparticle, 55 nm diameter) and 2.35 mg/m^3 (microparticle, 0.93 lm diameter) for 3 hours per day for 10 days straight. The number of C_{60} particles in the lungs of rats exposed to nanoparticles was higher than that of rats exposed to microparticles [141]. Protein levels in the bronchoalveolar lavage fluid (BALF) of rats exposed to nanoparticles were found to be significantly elevated. Necroscopy revealed no abnormalities, and serum chemistry showed minimal modifications. Although C_{60} was taken up by alveolar macrophages, no cellular infiltration was seen within the lung, indicating no inflammatory response had occurred. No steady-state lung burdens were obtained in this investigation, despite the predicted levels being reached after 130 and 145 days for nano and microparticles, respectively [155,157].

Fullerenes (4.1 _ 104 particles/cm^3, 96 nm diameter, specific surface area 0.92 m^2/g) were inhaled by male Wistar rats at a concentration of 0.12 mg/m^3 for 6 hours a day, 5 days a week, for 4 weeks. There was no evidence of severe inflammation or tissue harm during the 28-day inhalation exposure period or the subsequent 3-month observation period. Histopathological results showed no evidence of foreign body granuloma [162].

The researchers hypothesized that the tested dose was lower than the NOAEC for lung inflammation. Gene expression profiles showed upregulation of genes involved in the inflammatory response, oxidative stress, apoptosis, and metallo-endo-peptidase activity, as well as some genes linked to the immune system process, including major histocompatibility complex (MHC)-mediated immunity. This upregulation was likely an adaptive physiological reaction rather than a harmful one.

5.7.4 Intratracheal instillation

A study by Sayes et al. found no significant differences in lung toxicity for underivatized C_{60} (160 nm) and a highly water-soluble derivative $C_{60}(OH)_{24}$ when intratracheally infused into rats [163]. Quartz, on the other hand, elicited a proinflammatory and profibrotic reaction. Fulleroles, or polyhydroxylated fullerenes, may have safeguarding, antiinflammatory qualities at low concentrations, as they have been shown to attenuate a-quartz-induced neutrophilic inflammation [141,164]

Morimoto et al. analyzed neutrophil infiltration and expression of the chemokinecytokine-induced neutrophil chemoattractant (CINC) in the lung after 3 days, 1 week, 1, 3, and 6 months [157]. Xu et al. found that intratracheal instillation of 1 mg polyhydroxylated fullerenols $C_{60}(OH)_n$ per rat did not induce adverse pulmonary damage [165].

Inhalation and intratracheal instillation research has looked into the impact of fullerenes on the lungs, but few laboratories have access to the expensive equipment and large quantities of test substance necessary to undertake inhalation studies [166]. Intratracheal instillation once mimics higher exposure over a longer period, but the means by which underlying effects induced by a high dose rate (bolus delivery) are likely distinct from those induced when the same dose gets administered by inhalation over a longer period (months) [167]. Bolus-type dose delivery results should not be employed for risk assessment, and instead, inhalation study results are preferred for obtaining an INEL.

There has been one subchronic investigation on fullerenes, but no chronic studies have been reported as of yet. Subchronic studies indicate minimal lung damage of fullerenes, and the NOAEC is predicted to be substantially greater than the dose evaluated in the subacute investigations 28 days [162]. For the risk assessment of both short- and long-term exposure, it is suggested that the NOAEC from the 10-day study by Baker et al. [141] be used. Studies with post-exposure follow-up periods of 3 months after inhalation and 6 months after intratracheal instillation of up to 1 mg/animal did not show a persistent inflammation, so this seems justified and still conservative enough [141].

For a regulatory risk assessment, it would be helpful to have data on either subchronic or chronic exposure to the fullerene of interest.

5.8 Biological mechanisms and target organ toxicity

5.8.1 Inflammation, cytotoxicity, pro- and antioxidant properties

Nanoparticles exposed via inhalation can cause oxidative stress, inflammation, and chronic lesions such as fibrosis or cancer. Fullerenes, which are hydroxylated fullerenes, have been found to have proinflammatory effects at larger concentrations in the mouse lung [168]. In vitro studies suggest that inflammation may play a key role in the toxicity of fullerenes. Nano-C_{60} (0.24−2400 ppb) has been shown to be cytotoxic in multiple cell lines, causing increased reactive oxygen species (ROS) generation, lipid peroxidation, and membrane damage. However, fullerenes have potent free radical−scavenging activity, which is determined by factors such as water solubility and administered concentration [152,156,164,166,169,170].

Water-soluble derivatives of fullerene are more likely to be absorbed by the body and exercise their free radical−scavenging activity. Vitamin C, a well-known antioxidant, exhibits prooxidative activity at high levels. The antioxidant behavior of fullerenes is negatively impacted when exposed in high concentrations, as they are more likely to interact and form larger structures [133,168,171−173].

5.8.2 Cardiovascular effects

Several epidemiological and experimental studies [174] have reported a positive connection between exposure to ultrafine particles(especially from air pollution) and adverse cardiovascular consequences; such effects are also considered for manufactured nanoparticles. Endothelial cells internalized $C_{60}(OH)_{24}$ (1−100 lg/mL) after an acute exposure in vitro, and cell viability decreased with increasing concentrations of the compound [175]. Exposure to fullerenes for 10 days had a negative effect on cell adhesion and inhibited cell proliferation. Therefore, fullerene exposure may provide a risk for the onset or worsening of cardiovascular disease. Evidence presented by Radomski et al. suggests that fullerenes are less thrombogenic than other nanoparticles because they are less successful at eliciting the aggregation of platelets [176]. Protective benefits of $C_{60}(OH)_{24}$ against doxorubicin-induced chronic cardiotoxicity and hepatotoxicity were described by Injac et al. in rats with colorectal cancer [177]. However, there is currently no evidence that fullerenes can translocate from the site of exposure into the circulation, so exposure of the vasculature to fullerenes is currently only expected after direct administration into the blood, typically through injection. However, carbon nanotubes and other examples suggest that inflammatory mediators released from the lung may also induce cardiovascular consequences [178].

5.8.3 Immune effects

There may be immunological repercussions from being exposed to nanoparticles or ultrafine particles [179]. Using carbon nanotubes as an example, Mitchell et al.

demonstrated that lung inflammation can trigger the production of inflammatory mediators with systemic effects on the immune system [180]. However, due to their activity as radical scavengers, fullerenes have been demonstrated to be (also) antiinflammatory. Polyhydroxy C_{60}, also known as *N*-ethyl C_{60}, was shown to play an unexpected role as a negative regulator of allergic responses, as reported by Ryan et al. [181]. In the presence of fullerene particles, antigen-challenged cells (mast cells and peripheral blood basophils) demonstrated a considerable reduction in mediator release and an attenuation of IgE-mediated cytoplasmatic ROS levels. These fullerenes also blocked histamine release and temperature drop. In vivo and in vitro studies by Liu et al. found that water-soluble $C_{60}(OH)_{20}$ has particular immunomodulatory effects on immune cells such T cells and macrophages [148]. They had little to no effect on immune cell viability but did increase production of cytokines such tumor necrosis factor alpha, which aids in the cellular immune response by killing off malignant cells. $C_{60}(OH)_{20}$ inhibited the progression of Lewis lung cancer in vivo, an effect likely linked to an improved CD4/CD8 lymphocyte ratio.

5.9 Conclusion

A new and intriguing scientific topic has been developing over the past few years as a result of the accumulation of a large number of new findings and significant aspects of these carbon molecules. Fullerenes were at first thought to be inert molecules; however, due to their one-of-a-kind cage structure and their ability to dissolve in organic solvents, it was discovered that fullerenes are susceptible to exodehedral and endohedral functionalization. Redox reactions, on the other hand, yield endohedral adducts, which can include polymer films. Addition reactions result in the development of exohedral adducts. The correct knowledge of the principles that regulate the functionalization of the most prevalent fullerene (C_{60}) continues to be the major pivot to the ever-expanding openings that are available for the utilization of this third allotrope of carbon. It is recommended that additional research be conducted into the use of functionalized fullerenes in the storage of methane, in the catalysis process, and in the study of the environment. The direct application of fullerene and its derivatives to biological targets has the potential to have beneficial uses in the field of medicine. It is necessary for the related low toxicity of fullerenes to attract the attention of researchers who are interested in investigating these fascinating chemicals. The preceding studies suggest that fullerenes are less likely to cause inflammation than other nanoparticles, and there have been no reports of any systemic side effects. Under the assumption that fullerene-induced side effects indeed have a threshold, a risk assessment can be carried out.

Anticancer drug delivery systems utilizing photodynamic therapy (PDT), HIV drugs, and skincare products to slow down human skin aging are just some of the many potential commercial applications that have resulted from the recent surge in global research and development efforts. Industries will benefit from advancements in the fullerene industry. The high cost of producing fullerenes has historically been the primary restraint on the growth of the fullerene market. The current rate of price drop is unprecedented and will enable several new uses. Also, various commercial uses of fullerenes in industry have recently emerged.

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Plant-Derived Drugs for Alzheimer's Disease and Other Neurological Disorders

B. Sumithra, Sanjeeb Kumar Mandal, Bishwambhar Mishra, K. V. S. S. N. Mounika, J. Caleb Joel Raj, and C. V. S. Aishwarya

1 Introduction

Dementia often begins with the gradual loss of intellectual functions of the brain, such as memory, thinking, decision-making, learning capacity, attention, language, and visuo-spatial functions. Dementia is not specific to any disease but is rather caused by many neurological diseases including Alzheimer's disease (AD) vascular body dementia, Lewy body dementia, and Parkinson's disease [1, 2]. Alzheimer's disease is a neurodegenerative disease that causes nerve cell death and is the worldwide leading cause of dementia among 60–80% of patients. It is chronic, slowly progressive with late onset majorly associated with elderly people over the age of 65. The early signs associated are dementia, cognitive decline, and anxiety that decline the quality of daily living. Over time, these signs grow and become progressively more severe affecting the person's social and behavioral activities that lead to depressive feelings and finally death [3–5]. According to Alzheimer's Association, 50 million people globally are affected by Alzheimer's disease (AD) which is expected to triple by 2050 and increase to 150 million [6, 7]. Even the reported AD and dementia-related deaths are increasing globally due to many factors including growing population, aging, and increase in average lifetime. The death rate increased by more than 145% between 2000 and 2019 in the US population alone, thus creating a huge socio-economic burden on the healthcare system and society at large [3, 8, 9].

B. Sumithra (✉) · S. K. Mandal · B. Mishra · K. V. S. S. N. Mounika · J. C. Joel Raj · C. V. S. Aishwarya
Department of Biotechnology, Chaitanya Bharathi Institute of Technology, Hyderabad, Telangana, India
e-mail: sumithrab_biotech@cbit.ac.in

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2 Etiology of Alzheimer's Disease

The pathophysiological process of Alzheimers Disease (AD) is complex and multifactorial, with synaptic dysfunction of nerve cells as early events that lead to nerve cell death, tissue loss and finally brain atrophy wherein regions of the brain shrink and lose volume, which is severely seen in the hippocampus and cerebral cortex [3]. The major hallmarks of the AD brain are excessive deposition of amyloid plaques (amyloid-beta (Aβ) peptides) and highly phosphorylated tau proteins (tau tangles). Abnormal accumulation of Aβ oligomers and neurofibrillary tangles of phosphorylated tau proteins at the synaptic sites are highly neurotoxic that interrupt several synoptical signaling. Along with other processes such as oxidative stress, mitochondrial damage, generation of free radicals and inflammation, these aggregated proteins contribute to synaptic dysfunction and eventually lead to neuronal and synaptic degeneration. Another earliest pathological event is the deficiency of the vital neurotransmitter, acetylcholine (ACh). In Alzheimer's condition, the two primary cholinesterases (ChEs), acetylcholinesterase (AChE) and butyrylcholinesterase (BuChE), in the nervous system have increased activity, resulting in scarcity of ACh levels and ultimately inhibiting neurotransmission [3, 10–12]. The underlying mechanism causing AD pathogenesis (Aβ, NFTs, and synaptic loss) is still unknown [9]. Thus, in the current scenario, the inhibitors of acetylcholinesterase (AChE), clearance of aggregated proteins, neuron protection and regeneration, Anti-inflammatory, antioxidant activities are major targets for the development of drugs. Furthermore, genetic, environmental factors, and lifestyle are also proven to impact AD development to a great extent [12, 13].

Despite the research, treatment for this 100-year-old Alzheimer's disease has several challenges and remained untreatable [13]. Although the treatment strategies evolved in the last decade, there is no effective drug approved for the complete treatment of AD, besides only balancing the symptoms. Several synthetic drugs failed in clinical trials due to their limited efficacy and are also associated with severe side effects [11–13]. Currently, these results demand effective and safe pharmacotherapies from natural sources. Herbal medicine has played an important role in the treatment of neurological disorders and offers an alternative option. The polypharmacology concept of "multifunctional drugs (MTDs): one-compound multiple-targets" has gained attention in developing drugs for neurodegenerative diseases such as Parkinson's and Alzheimer's diseases. Considering this approach, the natural compound is of special interest for MTDS, as the safety and pharmacokinetics of synthetic multifunctional anti-AD drugs have several limitations [10, 14]. Several studies reported the potential of phytochemicals with significant anti-AD activity [10, 11, 15]. This chapter summarizes the most effective plants and their compounds against Alzheimer's disease and other neurological impairments in the following section.

3 Medicinal Plants Effective for Alzheimer's Disease and Other Neurological Disorders

3.1 Withania somnifera

Withania somnifera, also known as "Ashwagandha," is a perennial shrub native across India and belongs to the plant family Solanaceae or the nightshade family [16]. It is a nervine tonic, libido stimulant, and stress reliever used widely in Ayurveda to aid the system to acclimatize to stress. Because of its nootropic property, it enhances the cognitive behavior of the human brain [17]. It works as a hypoglycemic and hypolipidemic adaptogen. It has demonstrated anti-platelet aggregatory, anti-inflammatory, anxiolytic (anti-anxiety), neuroprotective properties and anticonvulsive [18]. Withanolides are the major medicinal constituent of *W. somnifera*. Dehydrowithanolide-R, Withanolides A-Y, withanone, withasomidienone, withasomniferin-A, withasomniferols A-C, withaferin A and ergostane-type steroidal lactones are among the therapeutic chemical components in ashwagandha. The β-sitosterol, phytosterols, sitoindosides, and alkaloids are other components [19].

Withania somnifera extract comprises a diverse variety of phytochemicals such as steroidal lactones, steroids, flavonoids, salts, alkaloids, and nitrogen-containing compounds. The plant has been shown to contain over 40 withanolides, 12 alkaloids, and sitoindosides. However, withanolides are primarily responsible for pharmacological actions [18]. These extracts possess various properties which can help treat AD. A few of those properties are discussed next.

3.1.1 Neuroprotective Property

Ashwagandha has been demonstrated to have free radical scavenging and antioxidant properties and also the ability to help maintain a robust immunity. Free radicals created during the onset and course of Alzheimer's disease have been demonstrated to be scavenged by a subset of these components. Furthermore, these compounds prevent amyloid-induced cell death in PC-12 cells and rat neural cells. Studies suggest that prominent Withanamide A and Withanamide C [20] (Fig. 1a, b) extracted from the fruits of somnifera plant protect PC-12 cells against amyloid peptide-induced cell toxicity. Withanamides A and Withanamides C cohere to the β-amyloid and suppress fibril formation [21].

3.1.2 Antioxidant Property

Various experiments were conducted on *W. somnifera* and the extract obtained from it proved its effectiveness in the treatment of AD and its related neurological dysfunctions [22]. One such study reveals that WS extract shields SK-N-SH cells

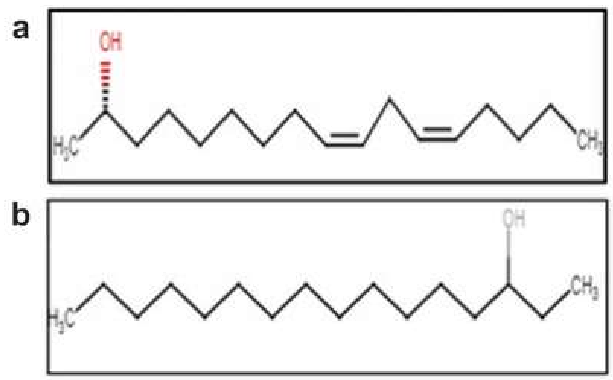

Fig. 1 Major Withanamides of *Withania somnifera*: (**a**) structure of Withanamide A (WA) and (**b**) structure of Withanamide C (WC)

(neuroblastoma cell line) from toxicity caused by Aβ peptide and acrolein and it was also able to lower the levels of ROS which in turn reduces the oxidative stress in SK-N-SH cells [23].

3.1.3 Acetylcholinesterase (AChE) Inhibitory Activity

The cholinergic supposition of Alzheimer's disease suggested the degradation of cholinergic neural cells in the forebrain and the significant decline of neurotransmission in the cerebral cortex and other areas are greatly responsible for the decline in cognitive function in patients with the disease. AChE is an important factor of cholinergic synaptic transmission and is involved in the fast hydrolysis of the neurotransmitter acetylcholine, which leads to the cessation of nerve impulses [23]. The reduction of this AChE activity promotes neuroprotection in patients suffering from AD. By using various models, it has been proved that the WS extract's AChE activity is significantly reduced in a dose-dependent manner [16].

3.1.4 Neuro-regenerative Property

Both axons and dendrites were significantly regenerated by a methanol extract of ashwagandha, in addition to reconstructing synapses in neural cells [24]. This aqueous preparation of *W. somnifera* was observed to boost cholinergic activity in rats, including increases in the content of acetylcholine and AChE activity, which might help to explain the cognition-improvement and memory-increasing effects [16] (Fig. 2).

The fundamental hindrance to the active ingredients withanolide A of *Withania somnifera* penetrating the blood-brain barrier (BBB). The main withanolides have not been reported to cross the BBB. However, withanamides (bioactive compounds from the fruit of *Withania somnifera*) have been proven to cross the BBB following intraperitoneal injection [17].

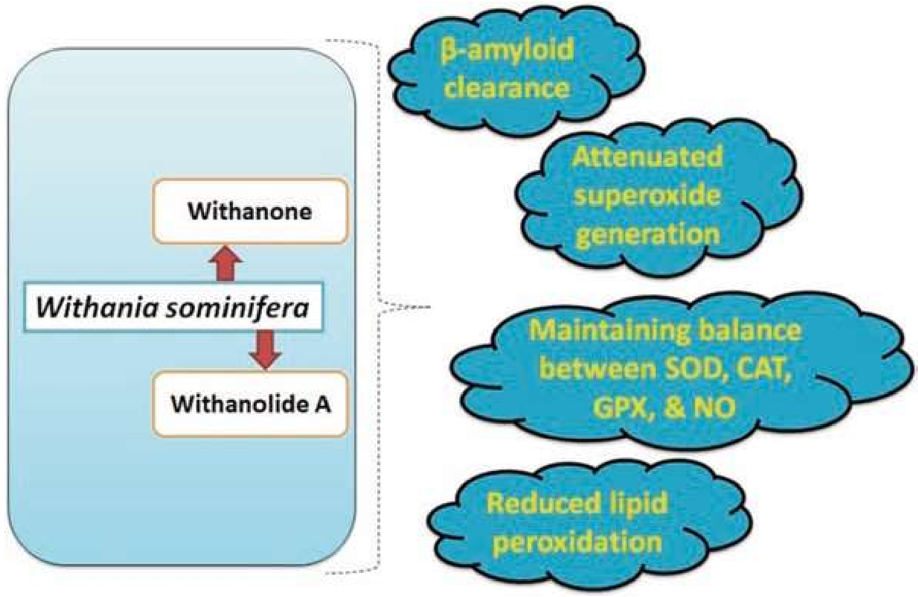

Fig. 2 Effects caused by the activity of *W. somnifera somnifera* extracts

From this, we can demonstrate that the *Withania somnifera* extracts have promising pharmacological potential. It exhibits various properties, that is, neuroprotection, neuroregeneration, AChE inhibitory activity, and antioxidant activity, which are key segments that have to be considered in producing a potential pharmacological effect against Alzheimer's activity**.**

3.1.5 *Withania somnifera* and Other Neurodegenerative Diseases

In addition to Alzheimer's disease, *W. somnifera* can potentially be used in treating other neural diseases like Parkinson's disease and Huntington's disease (Fig. 3). In Huntington's disease, Huntington's protein mutation has been found to produce neural dysfunctions and cell disintegrating processes, including transcriptional deficiencies, excitotoxicity, oxidative stress, inflammation, mitochondrial dysfunction, and apoptosis. The extracts of *W. somnifera* have been shown to regulate the functions of mitochondria of the neural crest cells and control the behavioral changes. It increases the antioxidant mechanism which protects the ganglia tissue against the reactive oxygen species.

In Parkinson's disease, the extracts of *W. somnifera* induce anti-inflammatory and antioxidant action which in turn increases the expression of dopamine receptors and prevents the fall of dopamine in the vicinity of the neural crest cells.

Fig. 3 Potential effects of *W. sominifera* are proven in different neurological disorders

3.2 Centella asiatica *(Gotu Kola)*

Centella asiatica is an annual herb of the Apiaceae family. It is one of the most significant revitalizing flora for the cells of CNS in Ayurveda, and it is said to be capable of boosting intellect, vitality, and memory. Triterpenes, asiaticoside, vellarin, asiatic acid, adecassoside, glycosides, madecassic acid, sapogenins, and centelloside are among the bioactive substances found in it [16]. *Centella asiatica* is believed to enhance levels of the neurotrophic factor BDNF (brain-derived neurotrophic factor) by activating MAP kinases (mitogen-activated protein kinase) [25] (Fig. 4). It is also renowned for its potential to enhance the healing of wounds in addition to its cognitive boosting properties. *Centella asiatica* blocks enzymes that disintegrate collagen while enhancing collagen production in preclinical trials, resulting in a faster wound healing rate [26]. Various in vivo and in-vitro experiments were conducted on gotu kola and numerous animal models were made to know about the working mechanisms of various extracts of *C. asiatica*. Some of the properties were thoroughly explained using animal models [27]. A few of them are mentioned in Fig. 5.

3.2.1 Neuroprotective property

As we know, amyloid plaques and amyloid accumulation in the cerebrovascular system are pathological markers of Alzheimer's disease [28]. *Centella asiatica* contains several components, the best researched of which being Asiatic acid in preclinical models. Asiatic acid has antioxidant and neuroprotective properties and crosses the blood-brain barrier [29]. It has been claimed to have stimulatory-nervine

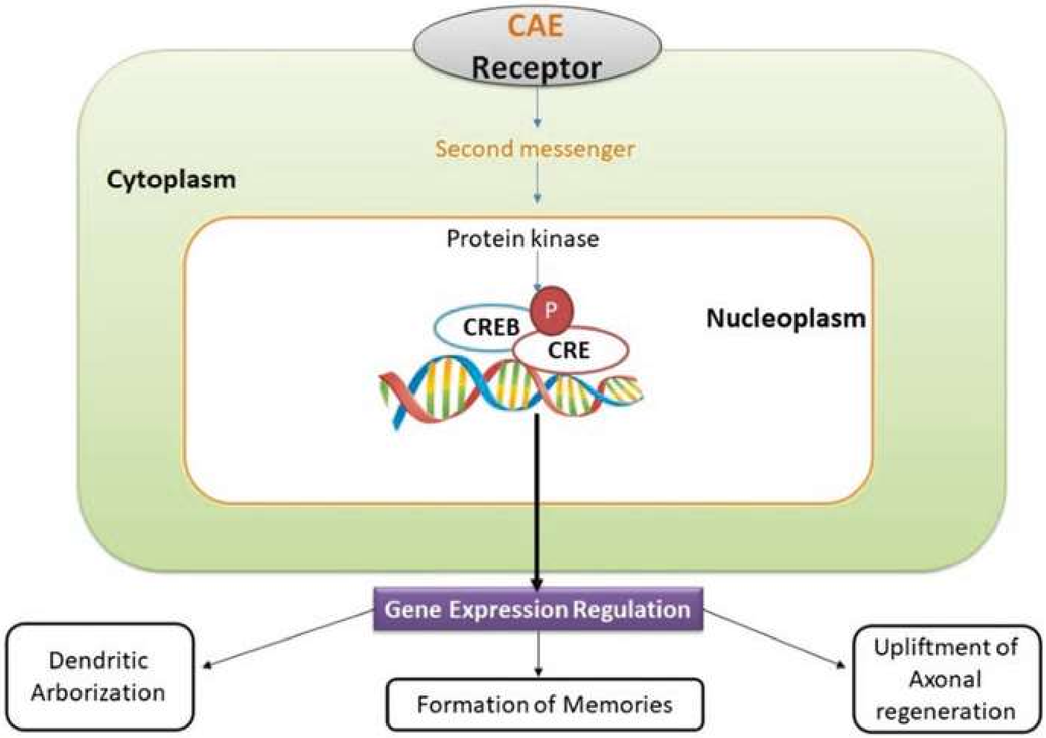

Fig. 4 Mechanism of action of *Centella asiatica* extracts

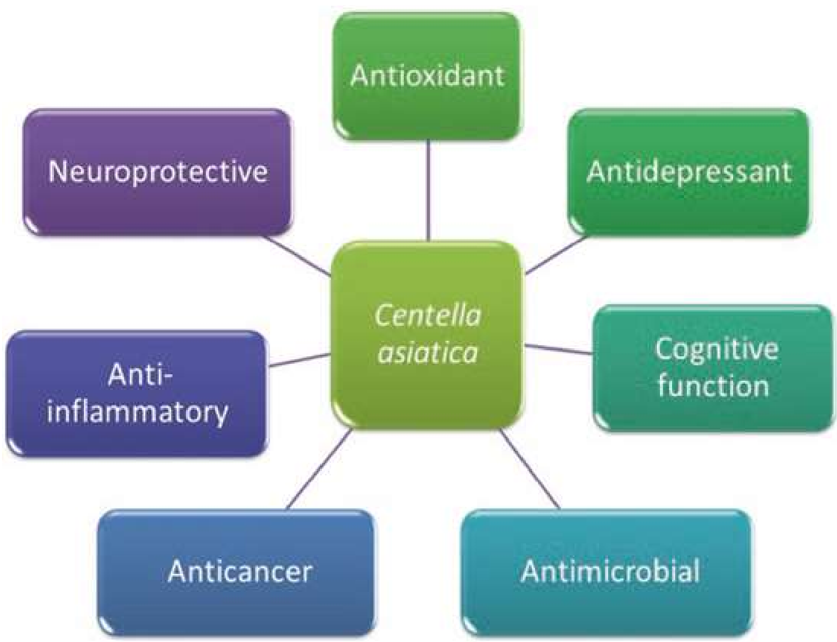

Fig. 5 Pharmacological effects of *Centella asiatica*

tonic, rejuvenate, sedative, anxiolytic, and intelligence-promoting properties on the CNS [30]. *Centella asiatica* leaf extract was also shown to affect the shape of hippocampal CA3 and amygdala neuronal dendritic arborization in newborn rats in a study. The pre-and post-colchicine Cornu Ammonis (CA) therapy boosted cognition, lowered malondialdehyde and nitrite concentrations, improved GSH levels, and boosted glutathione-S-transferase, catalase, and SOD activities [31].

3.2.2 Antioxidant Property

Oxidative stress (OS) seems to be a key event in AD's etiology. At the same time, aggregated Ab-induced oxidative stress is a trigger in AD's progression. Superoxide is considered to be the main ROS in the human body and it can be produced by the action of aggregated Ab1e40 on mitochondria which induces the activity of SOD (superoxide dismutase). The extracts of CA have been shown to significantly reduce this SOD activity and at the same time reverse the inhibition produced by SOD in neural cells. The only drawback to this activity is that the extracts work in a dose-dependent manner. These extracts also can moderate the activity of the enzyme catalase which helps in the hydrolysis of peroxide (H_2O_2) into water and oxygen based on cellular requirements. The data obtained from the experiment conducted on mice model for Alzheimer's disease have suggested that the extracts of *Centella* might increase GR and GPx activity (antioxidant enzymes which help in the breakdown of ROS) in differentiated PC12 (for neurotoxicity) and IMR32 cells (neuroblastoma cell lines), reducing oxidative stress in these cells [32]. Glutathione is one of the most common non-peptide intracellular thiols in cells, which is essential for cellular oxidative metabolism. It would be assumed that raising glutathione levels would lower ROS levels and oppose apoptotic signals [30].

3.2.3 Acetylcholinesterase (AChE) Inhibitory Activity

Hyperphosphorylation of tau protein, Aβ accumulation, and surging levels of acetylcholinesterase (AChE) activity are the most common factors in the pathophysiology of AD. Raw extract of *Centella asiatica* (RECA) was found to reduce AChE, inflammation, and OS activities in both in-vivo (Sprague Dawley rats) and in vitro (SH-SY5Y and RAW 264.7 cells). RECA has a higher percentage of glycosides than aglycones, with madecassoside being the most abundant, trailed by asiaticoside. RECA therapy of SH-SY5Y showed a concentration-dependent reduction in AChE levels and productivity as well as an increase in the concentrations of acetylcholine (neurotransmitter), which in turn improves synaptic communications [30].

3.3 Evodia rutaecarpa benthem

Evodia rutaecarpa Benthem, one of the most common species used in primitive Chinese medicine, is a fruit of the genus *Evodia* that is used to cure headaches, stomach discomfort, postpartum bleeding, diarrhea, physiological alterations caused by stress, inflammation, hypertension, and cancer and amenorrhea. It was recently reported to be a promising medication for controlling and preventing the onset and progression of Alzheimer's disease [33]. The components extracted from this species possibly possess antioxidant activity, antimutagenic and immunomodulatory activity and anti-AD and anti-inflammatory properties. Second, anticancer, anti-obesity, antinomic, antinociceptive, and antimetastatic properties are all present. These findings are extremely promising in terms of treating neurodegenerative diseases [34]. In vitro, the extracts obtained had a substantial inhibitory impact on acetylcholinesterase, and in vivo, they had an anti-amnesic effect [35]. Out of all the components extracted, three components have shown a reliable and efficient effect on treating Alzheimer's disease. They are evodiamine (Evo), berberine (BRB), and dihydroevodiamine (DHED) [33, 35, 36] (Fig. 6a–c).

3.4 Salvia officinalis

Salvia officinalis, commonly called Sage, is a part of the Lamiaceae/Labiatae plant family. Sage is a rounded perennial shrub that is native to the Mediterranean and Middle Eastern regions but is now found all over the world. Salvia is the family's biggest genus, with around 900 species. The aerial parts of the shrub, owing to their flavoring and seasonal properties, have often been used in the preparation of a wide variety of food products and traditional medicine. Ulcers, seizures, inflammation ulcers, paralysis, rheumatism, dizziness, gout, diarrhea, dizziness, and

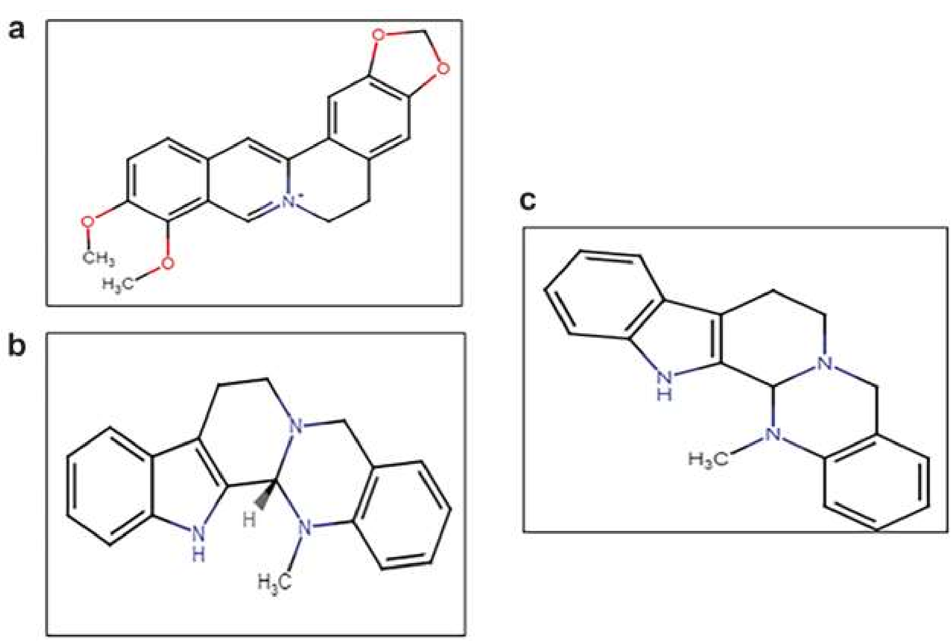

Fig. 6 Structures of effective phytochemicals of *Evodia rutaecarpa* Bentham: structure of (a) berberine (BRB), (**b**) dihydroevodiamine (DHED), and (**c**) evodiamine (Evo)

hyperglycemia are all the conditions wherein *S. officinalis* has often been used to provide the right treatment in the domain of folk medicine. This plant has been the subject of intensive research in the past few years, intending to document its classic usage and identify undiscovered biological effects. It has been found to have several biological effects such as anticancer [37], antinociceptive, antioxidant, anti-inflammatory [38], antimicrobial [39], antidementia, and antimutagenic properties so far [40].

The most important phytochemical components extracted from the various plant parts such as leaves, roots, stems, and flowers include carbohydrates and fatty acids; steroids; mono, di, tri and sesquiterpenoids and certain phenolic compounds, namely, tannins and flavonoids [41–43]. The majority of these were extracted from the aqueous extract, butanol fraction, alcoholic extract, or ethanoic extract of the plant.

The severe loss of the functioning of cholinergic neurons is a key characteristic of AD. *Salvia officinalis* has cholinergic properties; that is, it can mimic the action of acetylcholine which is a neurotransmitter. In various research, it has, therefore, been shown to have the potential to act as a source of innovative treatment for AD. The research was conducted to assess the efficacy and the dependency of a *Salvia officinalis* extract in individuals aged between 65 and 80 years with AD ranging from a very mild to a serious condition of the disease for 4 months using a fixed dosage of 60 drops/day. It was a placebo-controlled trial carried out in three different centers in Iran. As a result of these, the extract from *S. officinalis* performed better in terms of cognitive functions than the placebo-controlled group. No significant variations in side effects between the two groups were noticed and in the *S. officinalis* extract group, the agitation of patients was overcome, which however requires further confirmation. Thus, it was shown that a four-month therapy with a hydroalcoholic extract enhanced cognitive functioning, according to Akhondzadeh et al.'s randomized controlled experiment [44].

When looking at the mechanism, a possible interaction with the cholinergic system has been hypothesized as one of the processes responsible for *S. officinalis* cognitive and memory-enhancing effects. In research conducted on animals, the ethanolic extract of the leaves used showed an increased memory retention capacity in rats. Its interaction with nicotinic and muscarinic cholinergic systems was the major factor responsible for the entire process of memory retention [45]. The essential oil (EO) from the *S. officinalis* leaf extract was found to have an intriguing antioxidant activity with an IC50 value of 8.31 ± 0.55 mg/L. The inhibitory potency of EO against the three enzymes 5-lipoxygenase (5-LOX), acetylcholinesterase (AChE) and xanthine oxidase (XOD) was investigated for the first time in Tunisia. The result was that the investigated enzymes AChE (IC50 = 38.71 ± 2.09 mg/L), 5-LOX (IC50 = 36.15 ± 1.27 mg/L) and XOD (IP (percent) = 36.89 ± 1.83 at a final concentration of 50 mg/L in the well) were all completely inhibited by *S. officinalis* EO [46].

The leaves were also shown to have fungistatic, virustatic, and antibacterial biological activities, among others. In healthy mice, the hydroalcoholic extract of *S. officinalis* and rosmarinic acid (Fig. 7a), one of its main flavonoids, improved

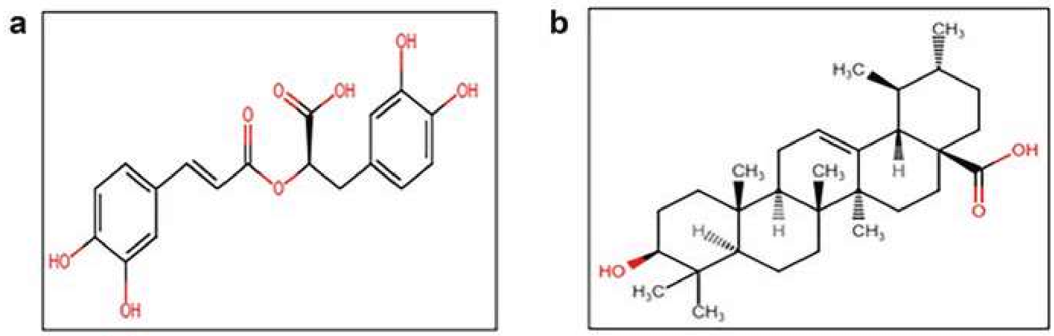

Fig. 7 Chemical structures of potential compounds of *Salvia officinalis*: (**a**) rosmarinic acid and (**b**) ursolic acid

cognition and delayed diabetes-induced impairments [47]. It also exhibits behavior by which the beta-amyloid (Aβ) fibril aggregation is stimulated and the Aβ development from Aβ1–40 and Aβ1–42 is brought to a halt in a dose-dependent approach. It also has the potential to compromise the integrity of Aβ fibrils [48]. Ursolic acid (Fig. 7b), another component abundantly found in *S. officinalis*, effectively suppresses AChE activity in vitro [49], thus suggesting that it might be beneficial to treat AD patients owing to its neurons-protecting action from the influence of oxidative stress and the ability to improve memory by inhibition of the AChE activity [50].

In conclusion, it can be stated that the *S. officinalis* L. extract can potentially serve as a propitious therapeutic strategy in dealing with Alzheimer's disease and AD-related dementia [51].

3.5 Rehmannia glutinosa

The generation of H_2O_2 and other reactive oxygen species is linked to neurodegenerative diseases. Catalpol (Fig. 8), an iridoid glycoside found in the root of the *Rehmannia glutinosa* plant, protects cells and mice from a variety of harmful stimuli [52]. Increased levels of reactive oxygen species (ROS) at the intracellular level produce oxidative stress, which is thought to be a typical cause of the death of neurons [53]. The balance between ROS formation and anti-oxidative activities may be disrupted as a result of aging and many neurodegenerative diseases such as Alzheimer's disease and Parkinson's disease [54].

Glutathione is a powerful antioxidant that protects cells from a variety of reactive oxygen species (ROS). Several linked enzymes confer various tasks for glutathione in live cells, in addition to the direct elimination of ROS by glutathione. In the metabolism of glutathione and the defense against ROS, astrocytes in the brain play a key role [55]. At the cellular level, astrocytes use two antioxidant mechanisms that can rapidly inactivate H_2O_2 to limit the risk of radical generation from peroxides. Reduced glutathione (GSH) acts as an electron donor in a glutathione

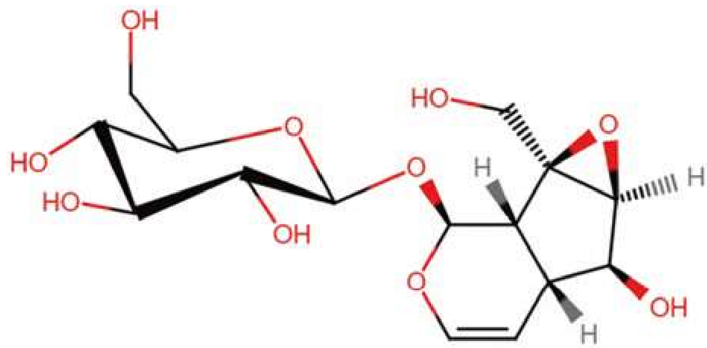

Fig. 8 Chemical structure of catalpol, an active compound of *Rehmannia glutinosa*

peroxidase-catalyzed process to reduce H_2O_2 to water. This process produces oxidized glutathione (GSSG), which is a glutathione reductase substrate. Glutathione reductase is in charge of cellular glutathione redox cycling, which is necessary for the detoxification of endogenous peroxides [56].

Astrocytes, the central nervous system's resident immune cells, have been linked to the maintenance and support of neurons. However, astrocytes can be triggered in response to inflammation, damage or disease in the brain, and activated astrocytes produce a variety of inflammatory mediators, including nitric oxide (NO), tumor necrosis factor-a (TNF-a), and reactive oxygen species (ROS) [57]. In comparison to neurons, astrocytes are found in greater numbers in the brain. They are likely players in information processing and play an important role in brain homeostasis. Catalpol pretreatment could reduce cell viability and cytotoxic effects in a concentration-dependent manner. Catalpol was found to protect astrocytes against H_2O_2, suggesting that it could be a potential protective agent.

Catalpol reduced intracellular ROS production, increased intracellular glutathione levels and successfully corrected the H_2O_2-induced decrease in glutathione redox cycling enzyme activity. Pretreatment with Catalpol, in particular, significantly increased glutathione reductase and glutathione peroxidase activity [58]. Catalpol's protection could be related to its ability to suppress ROS generation and cell death caused by H_2O_2, as well as its ability to increase glutathione mechanism cycling, including glutathione content and antioxidant enzyme activity. As a result, Catalpol could be a promising therapy option for a variety of neurodegenerative illnesses linked to oxidative stress [59].

3.6 Gastrodia elata

Gastrodia elata (GE) Blume (Orchidaceae) has been utilized in eastern countries for ages as a traditional herbal anticonvulsant. Vertigo, tetanus, and general paralysis are all treated with GE as an analgesic and sedative. Some of the key ingredients are gastrodin, vanillin, and hydroxybenzaldehyde. Organic acids, glucose,

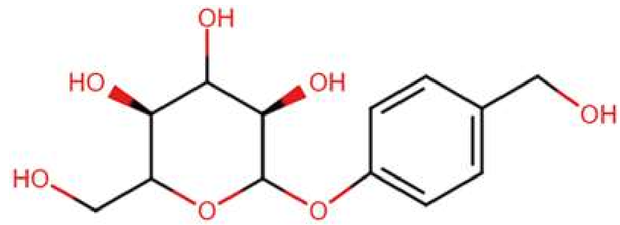

Fig. 9 Chemical structure of gastrodin, an active compound of *Gastrodia elata*

hydroxybenzaldehyde, phenolic compounds, and 4-(hydroxymethyl) phenol are among the other ingredients [60] (Fig. 9).

When tested on transgenic mice with epileptic seizures, an antioxidant and anticonvulsive effect was shown by vanillyl alcohol. Gastrodin is known to boost GABA levels by suppressing the GABA shunt. In a PTZ-induced seizure, glutamate-induced apoptosis in neurons is prevented by methanol extracts of *Gastrodia elata*, and the levels of GABA dropped significantly and glutamate levels were increased. It also showed free radical scavenging and antioxidant properties, as well as inhibiting kainate binding to glutamate receptors in kainate-induced seizures [61].

Excitotoxin and neuronal cell injury caused a dip in the levels of GABA and a rise in glutamic acid and its salts after brief global brain ischemia, which was mitigated by GE's & ether fraction or methanol extracts (EF & ME). The GABA was shown to reduce lipid peroxidation in the order 4-(hydroxymethyl)phenol > 4-(hydroxymethyl)-2-methoxyphenol>phenolicaldehyde>4-hydroxybenzaldehyde. The reduction of lipid peroxidation by ferrous ammonium sulphate [62] and melatonin at lowering H_2O_2 or Fe^{2+}-induced lipid peroxidation was also in this order of potency. Indeed, of the key compounds in GE's EFME, 4-(hydroxymethyl)phenol shows the maximum anti-oxidative effect, even more active than melatonin.

The antioxidant action of hydroxy benzyl alcohol was previously demonstrated to protect against ischemic brain injury. Melatonin prevents the formation of free radicals and the oxidation of lipids. Melatonin is also said to have the ability to prevent the Fenton process, which causes oxidative stress in a variety of metals, including ferrous ions. The high antioxidant properties of GE and its primary ingredients could be useful in treating lipid peroxidation-related neurological illness [63].

3.7 Cinnamomi cortex *(CC)*

The dried bark of *Cinnamomum cassia* is known as *Cinnamomi cortex* (CC), and it has been used to treat several potentially fatal ailments in traditional south Asian medicine. *Cinnamomi cortex* possesses glucose and lipid metabolism improvement, neuroprotection, anti-inflammatory, antioxidant, anticancer and other pharmacological properties [64].

At specific concentrations, three samples of cinnamon tannin demonstrate significant scavenging capacity against hydroxyl and 2,2-diphenyl-1-picrylhydrazyl (DPPH) radicals. The clearance rates of 2-diphenyl1-picrylhydrazyl radicals are

90.98%, 90.48%, and 89.38%, respectively, with the concentration of ethyl ethanoate extract, resin purification extract and crude extract about 0.04 mg/mL^{-1}. In all three samples, the hydroxyl radical clearance rates exceeded 65% and rose dose-dependently range from 0.1 to 0.6 mg/mL^{-1}. In the future, *Cinnamomi cortex* tannin could be employed as a natural antioxidant [65].

The therapeutic efficacy of *Cinnamomi cortex* extract on neurodegenerative diseases like Alzheimer's disease (AD) induced *Drosophila* and transgenic mice has been studied. According to the researchers, the lifetime of *Drosophila* induced with AD was extended, the motor capability was restored and the harmful Ab oligomer present in its central nervous system was destroyed. After ingesting the *Cinnamomi cortex* extract, transgenic mice had fewer 56 kDa Ab oligomers and plaques, as well as improved cognitive performance. According to the findings, CC extract protects PC12 cells from toxicity by reducing the synthesis of hazardous Ab oligomers. CC could be developed into an easy-to-use Alzheimer's disease prevention and treatment medicine. For the first time, Jana et al. discovered the mechanism through which sodium benzoate; one of *Cinnamomi cortex* plant metabolite for neurodegenerative diseases [66].

When tested on mice, sodium benzoate raised neurotrophic factors derived from the brain and neurotrophin-3 levels in the central nervous system via the PKA-CREB pathway. These data show that CC could be utilized to treat neurodegenerative illnesses as a main or secondary treatment. The Procyanidin type-a trimer (trimer 1), (E)-3-phenylprop-2-enal and chromen-2-one extracted from *Cinnamomi cortex* aqueous extract inhibited the swelling of the glial cell caused by deprivation of glucose and oxygen, according to Panickar et al. [67]. Trimer 1 reduced nerve cell swelling after ischemia injury by inhibiting the oxygen-free radical content and circulation of calcium. It also reduced glutamate excitotoxicity by halting the reduction in glutamate uptake. The researchers concluded that CC could be utilized to treat ischemia and other neurological issues [68].

4 Conclusions

For decades, numerous studies have been conducted to tackle different terrible neurological conditions. Although a few medications are currently available for the treatment of Alzheimer's disease, synthetic drugs have several limitations. To date, numerous drug candidates have been widely used in animal research and AD patients, but no significant medication has been able to effectively cure the clinical manifestations. Natural products, which involve the use of herbal drugs, could be a viable cornerstone on which treatment procedures can be streamlined. It is undeniable that the demand for such medical therapy is growing. Medicinal plant-derived biomolecules will help accelerate the development of new forms of treatment for AD. Combining different plant remedies with potential neuroprotective effects as MTDs could be useful in treating neurological disorders including Alzheimer's disease. When these medications are used together, they start to improve drug efficacy and patient adherence to therapy. In this chapter, numerous plants and various phytochemicals and their potential applications for the treatment of neurodegenerative disorders including Alzheimer's disease are discussed.

It is also important to adopt a holistic approach that includes herbal medicinal plants in our diet as well as trying to live in a collaborative environment that encourages social, mental and spiritual activities, thereby reducing stress, which is a risk factor for Alzheimer's disease. Foreseeing the recent progress, we anticipate that the intersection of medicinal plants will lead to successful therapeutic solutions for the treatment of Alzheimer's disease in near future.

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Chapter 52
Exploring the Potential of Biomedical Waste Management: Transforming Challenges into Opportunities for Sustainable Solutions

Chittepu Obula Reddy, Balaji Doolam, Naru Rakesh Reddy, Divyamshu Surabhi, Jyothika Meenakshi Kambhampati, Surabhi Nagamanju, and K. Rajagopal

Abstract According to a recent report by the World Health Organisation (WHO), improper handling of biomedical waste (BMW) is still an issue on a global scale, particularly considering the current COVID-19 pandemic. The rapid advancement of healthcare services has resulted in a huge rise in the creation of BMW. To stop the spread of infectious diseases and safeguard healthcare personnel, waste handlers, and the general public, biological waste must be properly separated, collected, treated, and disposed of. The research states that more than 16 million injections are administered annually around the world, resulting in the production of over 85 million tons of BMW. Given the current condition of global health challenges, this waste must be handled properly. These challenges can, however, be used as opportunities to find enduring solutions. The opportunities to employ sustainable solutions such as is used in agriculture as fertilizer, in energy generation as biogas, biofuel, electricity generation, etc., and in manufacturing and construction materials like cement. This book chapter emphasizes the potential for controlling BMW to inspire fresh thinking and encourage stakeholders to work together on durable solutions. By converting the

C. O. Reddy · B. Doolam (✉) · N. R. Reddy · D. Surabhi · J. M. Kambhampati
Department of Biotechnology, Chaitanya Bharathi Institute of Technology, Hyderabad, Telangana 500075, India
e-mail: doolambalaji1@gmail.com

C. O. Reddy
e-mail: cobulreddy_biotech@cbit.ac.in

S. Nagamanju
Department of Genetics and Biotechnology, Bhavan's Vivekananda College, Hyderabad, Telangana 500094, India
e-mail: nagamanju.biotech@bhavansvc.ac.in

K. Rajagopal
Department of Physics, Chaitanya Bharathi Institute of Technology, Hyderabad, Telangana 500075, India
e-mail: krajagopal_biotech@cbit.ac.in

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issues caused by BMW into possibilities, we can safeguard human health, safeguard the environment, and pave the way for a more sustainable and resilient future.

Keywords Biomedical waste · Cement · COVID-19 · Energy generation · Fertilizers · Infectious diseases · Medical waste

52.1 Introduction

All wastes produced by human and animal activities that are typically solid and are thrown away as unnecessary or unwanted are collectively referred to as solid wastes. Depending on where they come from, they can be divided into three categories: domestic waste, industrial waste (also known as hazardous waste), biomedical waste (BMW), or hospital waste (also known as infectious waste). Household waste, waste from renovation and demolition projects, sanitation waste, and street trash are all included in municipal solid waste. Industrial waste includes solid waste, liquid waste, gaseous emissions, and hazardous substances. It is any waste or byproduct of manufacturing processes, commercial operations, or industrial processes. Any solid or liquid waste produced during the diagnosis, treatment, or immunization of people or animals, as well as during research operations, is referred to as BMW (Patil et al., 2019a; Varughese et al., 2009).

Human anatomical waste, cytotoxic, chemical, surgical, pharmaceutical microbiological waste, biotechnological waste, sharps waste, leftover medications and drugs, liquid wastes, solid wastes including bandages, dressings, and plaster casts, chemical waste, and incinerator ash produced by hospitals and research facilities make up this waste stream (Dash et al., 2021; Kaur et al., 2022). The origin of the waste affects the physicochemical and biological characteristics, toxicity, and possible hazards of BMW. The biotic and abiotic components of the ecosystem are in danger when BMWs are disposed of improperly. All BMW must be disposed of in a way that is least damaging to people and the environment (Mastorakis et al., 2011; Rajor et al., 2012).

Not only in research institutes or hospitals but also through dialysis or insulin injection in rural areas or at home, can produce BMW. The BMW regulations, which were declared and created in 1998 by the Ministry of Environment and Forest, must be followed by all institutions that produce BMW (Deb et al., 2017). One of the biggest problems is the untreated direct discharge of hospital effluents into the municipal sewage system. For medical purposes, hospitals use a range of chemicals, such as radionuclides, medications, disinfectants, and solvents. Numerous of these substances cannot be treated with regular wastewater. Due to inadequate removal in wastewater treatment plants, pharmaceutical residues can be found in normal water, and dangerous compounds have the potential to damage the entire environment. The safety of persons who work at sewage treatment facilities, consume treated water, and utilize it at home is a developing concern (Patil et al., 2019b; Vasistha et al., 2018).

The various treatment techniques for managing BMW including adsorption, membrane separation, and nanoparticle-based techniques have been used to get rid of these contaminants. However, the bulk of research institutions focuses on recycling waste in methods that are good for the environment to minimize the problem of trash disposal (Manyele & Tanzania, 2004). According to WHO 2009, about 80% of hospital waste is not dangerous, of which 15% is infectious and 5% is both non-infectious and poisonous. The 20% infectious/non-infectious and hazardous waste includes chemical, pharmaceutical, radioactive, and heavy metal wastes, which are the root of major illnesses (Chartier, 2014).

This book chapter discusses the types, procedures to manage, environmental risks associated with improper disposal, and applications of BMW. It also describes the challenges faced biomedical waste management (BMWM) due to COVID-19 and the prospects of managing this waste.

52.2 Categorization of Biomedical Waste

BMW can be broadly classified as Health Care General Waste (HCGW) and Health Care Risk Waste (HCRW).

HCGW: About 85% of the BMWs do not possess any threat, i.e., are non-hazardous. Food remnants, paper cartons, packing materials, fruit peels, wash water, etc., constitute this type of waste.

HCRW: This is the part of medical waste that can act as a potential threat, i.e., it may cause illness or injury. It consists of:

a. Infectious waste containing pathogens like bacteria, viruses, fungi, and parasites capable of inducing illness in hosts susceptible to them.
b. Sharps like needles, scalpels, infusion sets, knives broken glass, etc., can cause cuts or puncture wounds.
c. Pathological waste or anatomical waste consists of parts of organs, tissues, body parts, human fetuses, and fluids of the body. These represent subgroups of infectious wastes, even though they might contain healthy body parts.
d. Pharmaceutical waste includes pharmaceuticals, medications, vaccinations, and serums that are out-of-date, unused, spilled, or otherwise tainted.
e. The genotoxic waste consists of cytotoxic drugs, radioactive substances, and patients' vomit, urine, or feces after cytotoxic treatments. And might possess mutagenic, teratogenic, and carcinogenic properties.
f. Chemical waste consists of toxic, genotoxic, corrosive, flammable, or reactive discarded solids, liquids, and gaseous chemicals.
g. Waste containing heavy metals like mercury, cadmium, and lead are discarded from hospitals. These are a subgroup of hazardous chemical waste.
h. Pressurized containers like reusable pressurized cylinders, cartridges, and aerosol cans are used to store gases for medical purposes. If burned or accidentally punctured, containers might explode.

i. Radioactive wastes comprise abandoned sealed radiation sources, radioactive liquids or gases, radioactively contaminated items, in vitro examination of bodily tissues and fluids, in vivo organ imaging, tumor location and treatment, and different radioisotope-based clinical trials (Thareja et al., 2015).

For an appropriate dealing of these contaminated wastes, BMW categorization or segregation is crucial. It is of the utmost importance to use the right mechanisms to reduce the amount of infectious waste, failing which will lead to risks to health (Subramanian et al., 2021).

52.2.1 Classification of Waste

On July 20, 1998, the Government of India's Ministry of Forest and Environment released guidelines for the proper handling and management of BMW. These regulations offered several codes for dealing with medical waste. All hospitals, nursing homes, clinics, dispensaries, animal houses, Research and Development (R&D), virology institutes, clinical diagnostic labs, veterinary institutions, and other similar institutions were informed of this policy. This applies to anyone who creates, collects, receives, transports, stores, or discards any type of BMW (Subramanian et al., 2021). According to the guidelines, 10 categories of waste were listed in Schedule I of the Ministry of the Environment and Forests (Thareja et al., 2015). Those categories are described in Table 52.1.

Table 52.1 Categories of biomedical waste

Category (Cat)	Type of waste	References
Cat 1	Anatomical waste from human	Thareja et al. (2015)
Cat 2	Animal waste	
Cat 3	Microbiological waste	
Cat 4	Waste sharps	
Cat 5	Pharmaceutical waste and cytotoxic drugs	
Cat 6	Solid waste (Substances contaminated with blood, and body fluids)	
Cat 7	Solid waste (Waste produced by disposable items besides sharps waste, like IV sets, catheters, tubing, etc.)	
Cat 8	Liquid waste	
Cat 9	Incineration ash	
Cat 10	Chemical waste	

52.2.2 Color Coding of Biomedical Waste

Waste from various categories was combined for disposal into the four color-coded bags as shown in Fig. 52.1.

The hierarchy of waste management (WM) includes reduce, reuse, recycle, recover, and refuse. These are referred to as the 5 Rs of management. Utilizing materials that are not biodegradable, such as plastic bags to customers, is avoided through reuse. In reduce, addition to reducing the package for customers, reuse materials for the intent. Recycling uses less energy than producing raw materials, and by dismantling the already existing materials, new products are created. Recover refers to energy recovery from the waste before discarding it (Bhalla et al., 2019; Subramanian et al., 2021).

52.3 Biomedical Waste Management: Techniques and Significance

BMW has the potential to produce significant detrimental environmental pollutants. In addition to solid hospital wastes like needles, plastic, and syringes, it comprises very proactive drugs, some of which are radioactive, and some microorganisms that are found in the excretions of various patients. If handled incorrectly, all the above mentioned wastes could include a considerable amount of pathogenic activity, which could lead to serious health issues like respiratory ailments, bacterial, fungal, viral,

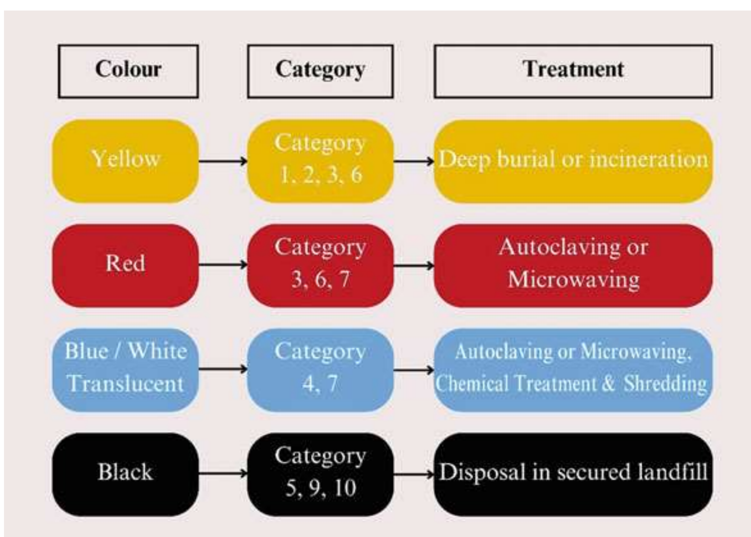

Fig. 52.1 Colour coding of biomedical waste

parasite infections, gastrointestinal problems, and more. Therefore, it is essential to manage the produced BMW (Jacob et al., 2021; Kaur et al., 2022).

The three Rs—reduce, reuse, and recycle—are the fundamentals of BMWM. 15% of BMW's total waste is hazardous, with 85% of its garbage being regular (non-hazardous) waste. The bacteria can enter the human body through cuts, abrasions, puncture wounds, and other openings since BMW includes sharps and syringes. The potential to ingest or breathe in biological waste (BW) may further raise the danger of infection. Helminthic infections, mycobacterium tuberculosis, streptococcus pneumonia, and typhoid are a few examples of diseases (Deb et al., 2017; Kumar et al., 2019).

52.3.1 Steps and Methods Involved in BMW Management

The various methods involved in BMWM include segregation, storage, transportation, and various treatments of BMW which are as follows (as shown in Fig. 52.2).

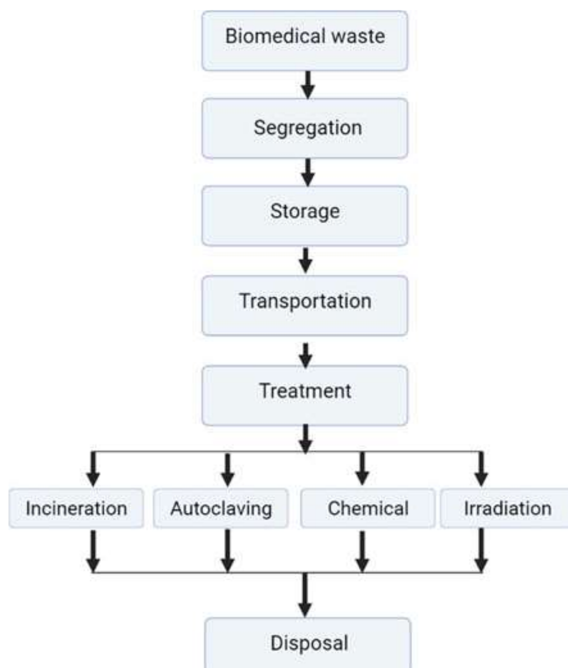

Fig. 52.2 Steps involved in biomedical waste management

52.3.1.1 Segregation

Waste segregation is essential and considerably improves the management of BMW. Management of BMW is only possible if we have control over the amount of infectious waste generated (Mishra et al., 2016). BMW needs to be collected in clearly marked, colored plastic bags. This collected waste can only be transported by authorized vehicles.

1. Recyclable but contaminated waste, including bottles, intravenous tubes, catheters, urine bags, syringes, and gloves, is placed in red-colored bags.
2. Human and animal anatomical waste, body fluids, contaminated trash including dressings, plaster casts, cotton swabs, and other clinical laboratory waste are all placed in yellow bags.
3. Solid chemical waste and incineration ash are stored in black bags.
4. Needles, scalpels, blades, and any other contaminated sharp objects that could cause cuts and punctures are placed in white bags along with other waste sharps (Mishra et al., 2016; Trivedi, 2022).

52.3.1.2 Storage

The healthcare facility should designate a specific space for the storage of BMW. The storage of BMW that is wrapped and contained should be carried out separately in a building, area, or place that is suitable for the amount of waste it generates, and the number of times waste is collected. Storage rooms need to be clean, secure, and sheltered from the elements like rodents, and disease-carrying insects (Patil et al., 2019a). The location where medical waste is gathered and kept has to be convenient for WM staff to access. The storage facility needs to be easily accessible for garbage disposal vehicles. To keep unauthorized people from using the storage, lock it. Storage containers must bear the "Biohazard" label (Chartier, 2014). Regular inspections and maintenance of the storage facility must be conducted.

52.3.1.3 Transportation

Transporting BMW can be done with carts and containers designed for the job. Regular cleaning of the carts is required. The name and address of the transporter should be conspicuously displayed on all off-site carrying vehicles. Ink should be used to color the biohazard warning sign. It is essential to ensure that the weight is safely distributed during transit. The rounded edges of these vehicles make them simple to clean. Before delivering disposable plastic to the vendor, it should be shredded. Biohazardous waste that has not been processed should not be retained for more than 48 h (Park, 2017).

52.3.1.4 Treatment

BMW treatment is the process that is utilized to get rid of the harmful effects of waste. A variety of treatment methods are used to increase the safety of waste disposal. It also reduces threats to the environment (Trivedi, 2022). The most widely used methods of cleaning and disinfecting BW include:

Incineration

This process is used to handle pathological and pharmaceutical waste and generates ash, gases, and heat. The ideal working temperature for incineration is between 800 °C and 1400 °C. It minimizes the negative impact of BMW on the environment by cutting waste volume by 90–95% (Ferdowsi et al., 2013; Sohal et al., 2021).

Autoclaving

To sufficiently disinfect the waste, this thermal technique utilizes carefully controlled contact between the BMW and the steam. The horizontal system which was designed specifically for the treatment of BMW is preferred due to its ease of treatment and operating safety. It effectively eliminates bacteria spores and pathogens. A temperature of 121 °C must be held for 60 min for small amounts of waste (Rajesh et al., 2013).

Chemical Treatment

This process is widely used to render liquid waste appropriate for local disposal. It makes use of a range of techniques, such as oxidation, reduction, precipitation, and pH neutralization, to convert waste into less hazardous substances. Chlorine, sodium hydroxide, or calcium oxide can all be used, depending on the waste type (Hirani et al., 2014).

Irradiation

Currently, gamma, electron, ultraviolet, and X-ray waste treatment technologies are employed in these systems. By introducing waste to radioactive cobalt-60, which emits gamma rays that are lethal to microorganisms, the process of irradiation disinfects the waste. It is very expensive when compared to other technologies, and safety precautions must be taken to safeguard staff from radiation-related illnesses and fatalities, including cancer (Zimmermann, 2017).

52.3.1.5 Disposal

Hazardous medical wastes can be securely disposed of in landfills after going through a number of disinfecting procedures because they no longer constitute a risk. It is important to properly plan and build a landfill site for the disposal of the reduced hazardous waste. To avoid leaching and other environmental problems like tainted groundwater, such areas must be regularly monitored. Solid waste can be routinely disposed of as long as it is uncontaminated general rubbish. Before being discarded, used masks and gloves must be kept in a paper bag for at least 72 h. It is preferable to cut or otherwise tear apart used masks before discarding them to avoid their reuse (Health Care Without Harm, 2020). Only individuals with appropriate credentials should be able to access the disposal locations. One of the more affordable, safe, and simple methods of getting rid of medical waste is encapsulation, which requires mixing an immobilizing chemical with the metallic drum or containers transporting the waste to act as a medium for blocking the waste material. The immobilized containers can be entirely sealed and disposed of in landfills once the medium has had enough time to dry completely (Chartier, 2014).

52.3.2 Significance of BMWM

The safety of hospital patients, medical staff, and locals is placed at risk by BMW. Inadequate disposal of BMW raises the possibility of air and water contamination, as well as the hazard of hospital-acquired diseases. Animals and scavengers may become ill as a result of open-space waste disposal practices, which transmit waste and diseases. Installing bins where BMW is generated, classifying BMW, eliminating recyclable waste, and disinfecting waste are four fundamental BMWM (Ramalingam & Saikumar, 2018). BMWM strategies place a strong emphasis on preventing waste from accumulating and recovering as much as possible from it when it does (Datta et al., 2018). Maintaining global cleanliness, public health, resource conservation, and ecosystem sustainability depends on planning the WM and recycling all of the waste generated at healthcare institutions. Recycling MW reduces the requirement for raw materials and the amount of waste that must be disposed of in a landfill. It reduces the risks and threats that a hospital might provide to the general public. It is feasible to lower the prevalence of illnesses like Human immunodeficiency virus (HIV)/acquired immunodeficiency syndrome (AIDS), sepsis, hepatitis, and others that are spread through contaminated medical equipment by appropriately managing waste (Murakami et al., 2003). The illegal sale of used needles, syringes, and other medical supplies can be stopped by employing the proper management measures (Arora, 2013; David & Shanbag, 2016).

52.4 Environmental and Health Risks Associated with Improper Disposal of Biomedical Waste

During medical procedures, any waste that can include infectious or possibly contagious elements is referred to as BMW. It is comprised of used needles, blood-stained bandages, samples from laboratories, expired pharmaceuticals, and other things that have come in contact with body fluids or have been contaminated with pathogenic agents (WHO, 2018).

The proper management of BW is essential for minimizing the negative health and environmental implications associated with healthcare operations. Approximately 85% of BMW is designated non-hazardous waste, whereas the remaining 15% is categorized as hazardous owing to the possibility of infectious, poisonous, or radioactive qualities. It is concerning that the 16 billion injections that are given annually across the world are not disposed of correctly, posing hazards. Inadequate disposal procedures are employed, comprising open combustion and incineration, which can emit toxic compounds such as dioxins, furans, and particle matter (WHO, 2018).

According to the WHO, incorrect disposal of BW poses substantial dangers. Each year, infected syringes cause approximately 21 million hepatitis B virus infections, an additional 2 million viral hepatitis C infections, followed by 260,000 HIV infections worldwide. Additional dangers exist in impoverished nations such as Kyrgyzstan from individuals rummaging through rubbish at trashcans and municipality workers being exposed to needle pricks and pathogenic organisms. Disturbing incidents, for instance, a smallpox epidemic in Vladivostok, when six children were infected with vaccinia after interacting with outdated immunizations that were openly dumped into a landfill. To safeguard both the environment and the people, it is vital to guarantee the safe disposal of healthcare waste in landfills. Another source of worry is the usage of radiation emitters in medical equipment (UNDP, 2021).

Managing medical waste and its byproducts improperly can have several detrimental health effects. Furthermore, harmful compounds present in pharmaceutical goods, for example, antibiotics and cytotoxic medications, can pose serious health hazards when discharged into the natural world during trash disposal or cremation. Chemically induced burns can occur during tasks such as disinfection, sterilization, or waste treatment, putting healthcare professionals' and waste handlers' health at risk. The combustion of medical waste releases particulates that can harm respiratory health by contributing to air pollution (WHO, 2018).

Additionally, these negative health impacts emphasize the significance of proper management and effective disposal practices to protect the health of both healthcare personnel and the general population. Untreated medical waste can contaminate groundwater, surface water, and drinking water if it is dumped in improperly built landfills. Even the application of chemical disinfectants in the treatment of medical waste can have a harmful influence on the environment (Chamberlain, 2021; WHO, 2018).

To summarize, poor BMW disposal poses major environmental and health dangers. Toxic chemicals and particulate matter can be released into the air by improper disposal procedures such as open burning and cremation. This can result in respiratory problems and air pollution. Furthermore, improper treatment of BMW will contribute to the spread of infectious illnesses and the possibility of puncturing injuries caused by sharp objects. Chemicals included in pharmaceutical items might pollute waterways if not disposed of appropriately. To preserve both the environment as well as the good health of healthcare personnel and the general community, correct disposal practices must be implemented.

52.5 Applications of Biomedical Waste

Numerous opportunities for reuse and recycling materials are offered by BMW, which helps a variety of sectors including agriculture, energy generation, and manufacturing/construction. The organic components of a BMW can be processed to create compost or nutrient-rich organic fertilizers for use in agriculture (Patil et al., 2019a; Sohal et al., 2021). By increasing crop yield, improving soil quality, and reducing dependency on chemical-based fertilizers, these fertilizers can assist sustainable farming practices (Dinesh et al., 2010; Goswami-Giri, 2011).

When it comes to energy production, there are numerous ways that BMW can be employed. Modern techniques like gasification, pyrolysis, plasma gasification, torrefaction, incineration, and anaerobic digestion can be used in BMW to convert organic waste into biogas, biofuels in solid, liquid, or gaseous forms, a renewable energy source. They provide an environmentally friendly alternative to fossil fuels that can be used to generate electricity and heat. The waste can also be put through additional processing to create biofuels, which can be utilized in cars or used in place of conventional fuel (Giakoumakis et al., 2021; Trivedi, 2022).

In addition, BMW can be used in the building and industrial sectors. BMW can also be used as a substitute for raw materials, eliminating the need for conventional resources and limiting environmental impact. It is used in the production of building supplies like cement (Kaur et al., 2019; Kumar et al., 2020).

By pursuing these possibilities, BMW can be utilized and managed in a way that not only minimizes the risks associated with its disposal but also supports the production of energy, the preservation of resources, and sustainable business practices in a variety of sectors. Let us see some case studies of the applications of BMW. The applications of BMW are summarized in Fig. 52.3.

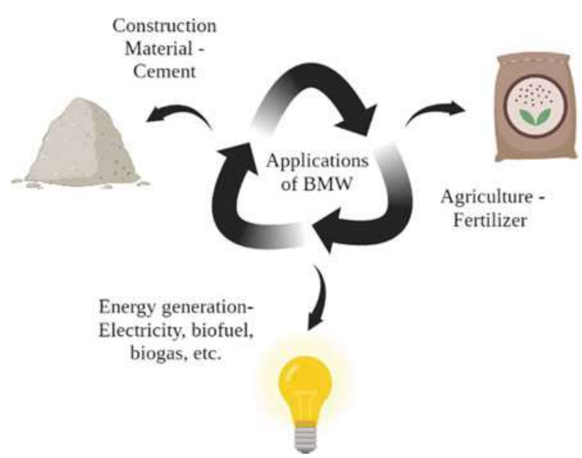

Fig. 52.3 Application of biomedical waste in agriculture, energy generation, manufacturing, and construction material

52.5.1 Application of Biomedical Waste in Agriculture

The waste produced upon human diagnosis, immunization, and treatment, as well as during operations for research and animal care, is referred to as organic BMW. BMW might harm the environment and people's health if it is not adequately controlled (Manzoor & Sharma, 2019). Composting is a sustainable disposal option and cost-effective bioremediation technique that can be used to dispose of medical wastes and remove organic contaminants. Neem and tobacco extracts are economically advantageous for local small farms and provide the best degradation of organic BMW. Therefore, these extracts can be employed to potentially transform organic BMW into fertilizer (Patil et al., 2019b).

By completely incinerating pathogenic hospital waste, BMW treatment facilities create Biomedical Ash Waste (BAW). In addition to heavy hazardous metals included in medications, medical equipment, and photographic materials, it is likely to contain 25–30 kg of fly ash every ton of waste materials. BAW is a source of hazardous heavy metals that can pollute the earth, water, and air (Sohal et al., 2021). As BAW is almost entirely made of macro and micronutrients, except for organic carbon and nitrogen, it has the potential to be used in agriculture. It might perform the role of chemical fertilizer to increase the productivity of many crops (Goswami-Giri, 2011).

According to the Mathur et al. (2006) study, Staphylococcus aureus, Proteus vulgaris, Pseudomonas pyocyanin, and E. coli were not isolated after twelve weeks of vermicomposting (VC), which showed that human pathogens did not withstand the process. Citrobacter frundii and aerobic spore-bearing bacteria, however, were identified. The composting process is accelerated and activated by earthworms, which considerably reduces the net amount of pathogenic BMW. Because it uses a unique breed of earthworms (Eisenia fetida and Eudrilus eugenia) to bio-oxidize and stabilize organic materials, VC is a more efficient technique to manage trash. It has also been found that it converts pathogenic microorganism-filled biodegradable garbage into innocuous waste that contains commensals like citroba, greatly reducing the volume of trash (Mathur et al., 2006). The BMW must be treated with 5% sodium hypochlorite (NaOCl) before being disposed of, according to previous investigations. It might undergo an early breakdown process when mixed with cow dung (CD) slurry. After that, VC can be utilized to continue treating it. A variety of epigeal worm species may be used for this. When used in this way, these worms can decompose BMWs more quickly. With the proper handling of BMW and the use of VC, this hazardous waste may be disposed of and recycled in a way that is both ecological and energy-efficient (Dinesh et al., 2010).

The study conducted by Goswami-Giri (2011), used various concentrations of BAW, CD, urea, and superphosphate to treat fenugreek and mustard. The type of crop and soil affect how effective these fertilizers are. The application of ash in the range of 1–1.5 g was found to be beneficial for the average growth of mustard and fenugreek. The yield of mustard and fenugreek is higher than control by between 54 and 55% and 35%, respectively (Goswami-Giri, 2011). Whereas in the research conducted by Sohal et al. (2021), the essential minerals from BAW were extracted and transformed into safe, nutrient-rich manure (vermicompost) using Eisenia fetida with CD. According to the findings, Eisenia fetida decreased the amount of heavy metals in the vermicompost. Heavy metals can be detoxified by earthworm body tissues called chloragocytes and intestinal bacteria. Earthworm VC may be a secure technique for nutrient recovery and purification from waste. Along with the CD, BAW may be utilized as a vermicompost in agricultural fields and is crucial for solid WM (Sohal et al., 2021).

The study by Patil et al. (2019a), establishes that organic BMW can be transformed into potential fertilizer by using neem and tobacco extracts. Total dissolved solids (TDS) were found to have decreased by 63.33%, and biological oxygen demand (BOD) and chemical oxygen demand (COD) were reduced by 86.15% and 95.30%, respectively. The physicochemical and phytochemical characteristics of the soil and plant were also improved, and there was no heavy metal contamination of the soil samples or tomato plants. A significant sign that this approach could reduce the load of synthetic fertilizer is the utilization of plant extracts to convert organic BMW into potential fertilizer (Patil et al., 2019a).

Whereas, another research by Patil et al. (2019b), investigated how organic BMW can be turned into fertilizer. The CD was collected in a sterile container and checked for any intestinal infections after blood, dressing, and used cotton swabs were collected. Following the preparation of the pure culture of bacteria and fungus, samples were degraded for 288 h. The BMW samples' physicochemical characteristics were examined, and the treated samples were combined with soil to verify their potential as a fertilizer. The tomato plant's phytochemical characteristics were also examined. The findings demonstrated that organisms and fungi performed outstanding organic BMW degradation, and it was discovered that the set D4's physicochemical parameters, treated soils, phytochemicals, and morphological parameters of a plant were high. This shows that pathogens found in BMW can be successfully destroyed by microbes (Patil et al., 2019b).

The disintegration of Plaster of Paris (POP), which includes BMW from hospitals, is a simple, inexpensive, safer (non-toxic), and highly efficient procedure. POP is entirely dissolved using ammonium bicarbonate (ABC) solution, resulting in goods with higher value. The byproducts of the procedure were calcium bicarbonate and ammonium sulfate. In the building sector as an additive and in agriculture as fertilizer, respectively, are both by products employed. This practice benefits the environment and saves money. In addition to being antibacterial, the ABC solution had antimicrobial properties on some of the tested microbes. Therefore, it may be beneficial to use a 20% ABC solution to disinfect POP BW obtained from patient samples such as burns, accidents, fractures, and dental problems. Additionally, it is a good substitute for POP incineration, which can also prevent air pollution and maintain a safe atmosphere (Navale et al., 2019).

52.5.2 Application of Biomedical Waste in Energy Generation

Energy consumption throughout the world has skyrocketed from 43,301 TWh to 165,320 TWh as of 2021 according to the primary energy generation report generated by Ritchie et al. (2022). This increase in power consumption has increased the demand for the discovery of multiple energy generation sources. Leading to the point where the world understood the gravity of pursuing energy-generating sources without much regard for the consequences of overly exploiting the available resources. This steered the world to walk towards decarbonizing the world's energy supply. Ritchie (2021) compiled the world energy data to compare the energy that is derived from nuclear and renewables; in the hope to address whether the world is taking progressive steps toward decarbonizing energy. The report stated that the rapid growth in low-carbon energy due to the focus on wind and solar power had set the emphasis on the transition from fossil fuels to renewables and nuclear energy for decarbonization. Therefore, it is of prime significance to concentrate on generating energy from more low-carbon energy sources.

One of the most abundant sources of sustainable energy is the concept of generating energy from waste. As it manages to address the crucial waste management challenges faced when progressing towards a circular economy and a sustainable world. Circular Economy (CE) refers to the solution that would allow nations, organizations, and consumers to live in harmony with the environment enclosed in the product life cycle loop (Korhonen et al., 2018; Xiao et al., 2020). This enables focus on recover-reuse-recycle to reduce the burden on natural resources like fossil fuels. To attain this, it is important to implement waste-to-energy (WTE) systems, which ensure to tackle issues like climate change, and land usage and strive to decrease the reliance on fossil fuels (Pavlas et al., 2011). To aims to recover energy from waste in the form of operational electricity, fuel, and heat (Tan et al., 2015).

The sudden occurrence of the COVID-19 pandemic caused an increase in waste involving household waste and an exponential rise in biomedical waste volumes. Municipalities around the world were faced with a sudden challenge to formulate sustainable approaches to manage waste. For instance: in India, the produced COVID-19 waste added 15–20% to the existing wastage (Khosla et al., 2022). The management of the growing BMW had become a major concern for the countries, this pushed them to focus on implementing proper disposal and possible recover-reuse-recycle systems.

Management of BMW is crucial for ecosystem sustainability as it reduces the amount of garbage disposed of in landfills. Inadequate BMW disposal can lead to hospital-acquired infections and infectious disease transfer to animals and scavengers. Effective BMWM is necessary to reduce these risks (Trivedi, 2022). Leveraging BMW to generate electricity not only handles these dangers by minimizing the amount of garbage that ends up in landfills but it also allows us to widen the sources of our energy, mitigating our reliance on fossil fuels (Argo, 2022). The production of electricity from BMW is consistent with the ideas of a circular economic model, which transforms waste products into valuable resources.

52.5.2.1 Technologies for Energy Generation from Biomedical Waste

The energy produced during BMW disposal is acquirable through a variety of methods. The produced energy is in the form of electricity, liquid fuel, and solid fuel. The procedures in practice are incineration, pyrolysis, gasification, anaerobic digestion, technology that utilizes co-thermal carbonization, the buildup of enzymatic fuel cells, and the employment of pretreatment with acid alongside enzymatic saccharification (Giakoumakis et al., 2021). Multiple studies have been conducted to assess their efficiency in generating energy.

52.5.2.2 Incineration

Incineration is a common way to dispose of healthcare waste while simultaneously generating power. In a controlled environment, garbage is burned at temperatures that range from 800 to 1200 °C. The heat produced by the process of combustion can also be utilized to produce steam, which is thereafter utilized to produce either heat or electricity for a variety of applications (Giakoumakis et al., 2021).

Dihan et al. (2023), devised a study to investigate the position of healthcare waste management in Bangladesh and how it may be made more sustainable using a circular economy. They concluded that incineration when paired with energy recovery and implemented alongside microwave sterilization, results in a method that causes the least environmental impact (Dihan et al., 2023). Similarly, the investigation carried out by Chaiyat (2021) examined the efficiency of an incinerator that acts on infectious clinical waste by utilizing R-245fa (Organic Rankine cycle) as its working fluid. The investigation concluded that the proposed system could transform 184.42 kg/h of BMW into a power of 23.65 kW_e with an efficiency that ranges from 0.89% to 0.90% (Chaiyat, 2021).

52.5.2.3 Pyrolysis

Residential and commercial garbage are both treated using pyrolysis, a solid waste management technique that is usually implemented as a substitute for incineration. It requires breaking down waste in the shortage of oxygen at high temperatures. Byproducts of this technique might be solid, liquid, or gas. Pyrolysis may also transform low-energy compounds into high-energy fuels. Many reactors are used for pyrolysis, each optimized to treat a certain amount of waste. The four types of pyrolysis include slow pyrolysis, fast pyrolysis, thermal pyrolysis, thermal cracking, and catalytic pyrolysis (Dharmaraj et al., 2021).

According to the study done by Dharmaraj et al. (2021), the discarded plastics of COVID-19 medical disposals can be effectively broken down using pyrolysis. This plastic waste may be pyrolyzed to produce fuels in the three states of matter (solid, liquid, and gas). Due to its simplicity and environmental friendliness, this approach may eventually take the role of incineration in the treatment of plastic garbage left over from the COVID-19 epidemic. Likewise, (Manegdeg et al., 2020) deduced that the WTE plant established in Quezon City that made use of the method; cyclic pyrolyzer-Rankine, was able to generate a payback period of 5 years with a return on investment (ROI) of 297%. Suggesting that the benefits incurred would be four times the investment costs (Dharmaraj et al., 2021).

Thermal cracking, a type of pyrolysis; is where a polymer is heated up in an inert environment causing it to break apart into smaller pieces, like liquids and gases. Some of the resulting substances are similar to things like paraffin wax and gasoline, while others are solid leftovers. The term cracking implies the action of pyrolysis on alkanes (Castrovinci et al., 2008).

Rasul et al. (2021), employed thermal cracking to the plastic debris of BMW to generate 52% liquid fuel oil that presented a higher heating value (HHV) quite similar to commercially available diesel, i.e., 41.32 MJ/kg. It was also concluded that this process can work as a substitute for incineration as it can yield clean fuels that possess substantial energy capacity. However, this method is not applicable in large-scale biomedical waste management (BMWM), suggesting further research that should be explored on a pilot scale. Another similar study was carried out by Som et al. (2018) by using thermal pyrolysis on the plastic portion of BMW, their team was able to generate a yield of 53%, and the produced pyrolytic oil had similar HHV to that commercially available diesel.

52.5.2.4 Gasification

The idea of generating heat and electricity from medical waste while reducing pollution is a great one. This may be achieved by using a gasification process that transforms organic compounds into producer gas or Synthetic gas (Syngas). Before oil and gas became more widely available, gasification was favored. However, this trend has since faded (Woods, 2020). Similarly, a type of gasification technique called plasma gasification also produces syngas, but unlike conventional gasifiers, it makes use of ionized gas–plasma and high temperatures. It is regarded as an environmentally friendly and efficient approach to managing BMW (Erdogan & Yilmazoglu, 2021).

To cope with medical waste, the research by Dong et al. (2023), advises integrating a system for recovering waste heat using a plasma gasification device. Produced combustible gas will be utilized to create electricity, and the heat from the waste is going to be applied to heating steam and water. Their calculations suggest that this design can create 4.17 MW of power while also disposing of silica powder weighing 4320 tons and BMW weighing 23,040 tons per year. The investment cost of executing this concept is approximately $18,843.65, however, it has a 3–4 year payback period, making it a viable and promising commercial choice (Dong et al., 2023).

A similar model explored by Kaushal et al. (2022), worked to explore the characteristics of plasma gasification and how well it can be adapted to the Indian economy. They summarized that the byproducts slag, which can be used for manufacturing building aggregates and the other byproduct syngas have the capacity to power compression ignition engines. However, this technology requires the calculated actions of the Indian government for its effective implementation (Kaushal et al., 2022).

52.5.2.5 Anaerobic Digestion

The production of energy from BMW can also be accomplished by anaerobic digestion. It is the breakdown of organic materials by microbes in the absence of oxygen. Anaerobic digestion may transform organic elements in BMW into biogas (methane and carbon dioxide). This biogas may subsequently be converted into heat and power. Anaerobic breakdown serves as a sustainable and environmentally friendly power source that lessens the release of greenhouse gases from waste while producing useable energy (Ismail & Talib, 2016).

Ismail and Talib (2016) explored thermophilic biodigestion to increase the yield amount of biogas, which increased by 92%. They suggested that this methodology could be a better alternative to the incineration of BMW, as it can effectively generate energy from lignocellulosic and cellulosic BMW.

52.5.2.6 Torrefaction

Torrefaction, although it is not commonly used for BMWM; alters the characteristics of BMW, resulting in higher quality fuel for gasification and combustible applications. Torrefaction creates a comparatively dry product, reducing or eliminating the possibility of organic breakdown (Xin et al., 2019).

Xin et al. (2019), utilized the torrefaction methodology to produce fuel from herbal medicinal wastes. The obtained results denoted that the fuel acquired had great combustible properties. The study also showed that this technology has great compatibility with lignocellulosic biomass and can enhance its HHV.

To summarize, the BMW generation is critical in meeting the rising global need for energy and in its transition towards a more energy-sustainable energy economy. We can reduce landfill trash, lessen environmental consequences, and broaden our energy sources by producing electricity from BMW. For energy generation from BMW, many processes which include incineration, pyrolysis, gasification, anaerobic digestion, and torrefaction have been investigated. Each technique provides distinct benefits and efficiency in the generation of electricity, liquid fuel, and solid fuel. To harness the energy potential of BMW and support a circular economy, more investigation and use of these technologies are required.

52.5.3 Application of Biomedical Waste in Manufacturing and Construction Material

As the concrete revolution accelerates, more natural resources are being used. Utilizing these resources throws the environment out of balance and reduces its usefulness to humans. When BMW is recycled rather than carelessly discarded, pollution levels are minimized. New methods for substituting components with BW are being tested to maintain the stability of the concrete. Along with the scarcity of natural resources, the disposal of toxic waste is an important issue that needs to be addressed. Effective utilization of these BWs is necessary due to the increase in the amount of waste that must be transported and the shortage of dumping sites. BMW from Personal Protective Equipment (PPE) kits, plastic BMW, and incinerated BAW are examples of BMW materials that could be used as an alternative. Below is a discussion of how these possibilities might be used (Kaur et al., 2019).

The Marshall Stability test (MST) conducted by Surya et al. (2018), reveals that using recycled plastic bags and BMW plastic to partially replace the bitumen on flexible pavement improves workability and strength qualities. If we were to put this into practice, there is no doubt that the amount of BMW that contributes to environmental issues like contaminated drinking water and health problems would decrease. When compared to traditional flexible pavements, the use of waste plastic in flexible pavements produces good results. According to the MST, the ideal plastic usage might be 15%, 20%, 25%, and 30% of bitumen. Additionally, it has stopped the spread of pathogens from BMW and the release of dangerous substances. The flow value rises and the proportion of air spaces in the mixture slowly declines when plastic waste is added to the mixture. Roadway construction uses a lot of leftover plastic, which reduces waste. This process will reduce the amount of BW that is released into the environment (Surya et al., 2018).

Kumar et al. (2020), have investigated if BAW can be used in place of Ground Granulated Blast Furnace Slag (GGBS) in Geopolymer Concrete (GPC). Results showed that the compressive strength of GGBS with up to 10% BAW replacement was higher than that of a usual mix (0% BAW). More BAW increases the Initial Setting Time of GGBS-based GPC. When BAW is added, GGBS-based GPC gains 10% more strength compared to GGBS alone. The strength of the geopolymer concrete reduces when BAW addition increases by over 10%. When NaOH molarity is at a value of 13, the compressive strength increases; after this value is exceeded, the compressive strength decreases. Therefore, 7% of BAW can be substituted with 13 molarity of NaOH in GGBS-based GPC (Kumar et al., 2020).

Mohan et al. (2022) developed a new composite incorporating PPE waste as well as river sand and M sand as fillers. Comparing the composite to conventional building materials, such as mud bricks and other traditional cementitious materials, yielded encouraging results with superior strength and durability attributes. Lower filler ratio composites exhibit compressive strengths of 25 MPa and higher, demonstrating the new composite's potential as a building material. Tropical conditions are suggested as prospective uses for the composite, and its greater acid resistance justifies its usage in locations where acid rain is a problem. Tensile and flexural strengths are stronger than mud bricks and other conventional building materials, and their thermal conductivity is lower than that of cementitious construction materials. This study demonstrated the possibilities for the efficient use of PPE waste in the construction industry (Mohan et al., 2022).

The investigation mentioned by Kumar et al. (2016) has concluded that ash from BMW can be utilized to successfully manufacture concrete. BAW is used to make concrete, which is less workable than conventional concrete. As the replacement level rose, the concrete's density slightly decreased. However, up to a replacement level of 15%, the density of replacement concrete was roughly 99% of that of regular concrete. The BAW-based concrete's compressive strength was equal to or greater than that of conventional concrete (Kumar et al., 2016).

Biomedical waste incinerator ash (BMIA) has been used to enhance the properties of self-compacting concrete (SCC) in a study conducted by Nataraja et al. (2023). The study found that 5% of BMIA was the proper level of substitution in SCC, resulting in a 5% increase in compressive strength and a 5% increase in chloride permeability. It was also demonstrated that SCC samples with BMIA had lower chloride permeability, encouraging pore refinement and microstructure densification. The results of the X-Ray Diffraction (XRD) test showed that cement and BMIA particles have a crystalline form. Finally, it can be inferred that 5% of BMIA can be substituted for cement to create SCC mixes, which improve many of the performance qualities of concrete and provide a sustainable and eco-friendly option (Nataraja et al., 2023).

52.6 Challenges in Biomedical Waste Management: COVID-19 Perspective

A law regulating healthcare waste management (HCWM) was passed as a result of public controversy about practices for disposing of medical waste and multiple public interest litigations (PILs) filed in various courts. The Ministry of Environment and Forests of the Government of India developed the Biomedical Waste (Management and Handling) Rules in response to the appalling conditions surrounding the management of BMW, and they went into effect on July 20th, 1998 (Gupta et al., 2009).

The Central Pollution Control Board (CPCB) data from 2007 to 2019 demonstrated a consistent rise in the daily production of BMWs. BMW generated only 410 tons per day in 2008, but during the following ten years, that number rose to 619 tons per day. With a treatment capacity of 800 tons per day, India has established numerous BMW treatment facilities in various states and union territories (Chand et al., 2021). Due to the unexpected rise in COVID-19 patients and the additional CPCB guidelines put in place during the pandemic, the daily BMW generation rate has abruptly surged to 850 tons per day. There is a vital need to supervise the BMWs based on specific parameters for the potential COVID-19-like pandemic in the future because

Fig. 52.4 Challenges of BMW management due to COVID-19

the abrupt increase in the number of BMWs during the pandemic has shown to be exceedingly harsh for the treatment providers and medical administrators (Goswami et al., 2021; Ojha et al., 2022).

It is necessary to deal with the possibly contagious trash produced during the home quarantine period. This involves ensuring that the deceased COVID-19 patients are properly buried or cremated, preventing the virus from spreading through feces and washing contaminated objects with more biocidal chemicals, detergents, liquid soaps, or just plain water. Additionally, water bodies are at risk from increased usage of biocidal chemicals, detergents, liquid soaps, or just plain water used to wash contaminated material, and it is important to handle any potential environmental issues brought on by the volume of COVID-19 waste (Klemeš et al., 2020; Sharma et al., 2020).

Furthermore, PPE is currently used by the general public, patient attendants visiting hospitals, and care centers, office personnel in public and commercial offices, airline staff, and railway officials, and any error could have disastrous consequences (Capoor & Parida, 2021). Below are the top 8 challenges in managing BMW due to COVID-19 (also described in Fig. 52.4).

52.6.1 Increased Volume of Wastes

The COVID-19 outbreak has resulted in a marked rise in the production of biomedical waste. The usage of PPE by healthcare workers, such as masks, gloves, and gowns, as well as the disposal of testing kits, syringes, and other medical supplies, have been cited as the causes of this rise. Enough infrastructure and resources are needed to manage and dispose of this expanding volume of trash (Sharma et al., 2020; Tripathi et al., 2020).

52.6.2 Lack of Segregation of COVID-19 Waste

The proper separation of COVID-19-related garbage, such as contaminated PPE, testing kits, and other medical waste, is crucial for effective management. However, in the present situation, there may be a lack of understanding or adherence to necessary waste segregation methods, contributing to the mixture of COVID-19 waste with conventional healthcare waste. This may cause risks to waste handlers, raise the amount of harmful trash, and prolong the disposal method (Capoor & Parida, 2021; Klemeš et al., 2020).

52.6.3 Safe COVID-19 Waste Management and Disposal

COVID-19 trash, including contaminated PPE, testing swabs, and medical equipment used on infected patients, must be handled, and disposed of using specific procedures to prevent the virus from spreading. This calls for carefully sorting, packaging, and marking waste as well as transporting it in approved trucks and containers. Assuring the proper collection, transportation, and handling of COVID-19 garbage presents unique challenges in terms of infection control and maintaining the safety of waste handlers and the general public (Chand et al., 2021; Gahlot et al., 2019; Sharma et al., 2020).

52.6.4 Lack of Infrastructure and Facilities

Especially in low-resource areas with poor WM infrastructure, many healthcare facilities lack adequate facilities for the segregation, storage, transportation, and treatment of BMW. Inadequate infrastructure can lead to delays, improper waste disposal, and an increase in risks to the environment and public health (Das et al., 2020; Dehal et al., 2022).

52.6.5 Training and Awareness

WM specialists and healthcare personnel need to obtain the appropriate instruction and training to successfully handle BMW. Patient care and emergency response, however, have taken precedence during the pandemic, leaving little time or money for intensive training initiatives. Poor WM, disposal, and segregation practice could result from this, which might violate environmental and safety norms (Gahlot et al., 2019; Goswami et al., 2021).

52.6.6 Financial Challenges

Many healthcare facilities, especially those that are smaller or situated in areas with limited resources, may have financial challenges due to the high cost of establishing effective BMW protocols. Due to the high costs of procuring the appropriate waste storage containers, vehicles, treatment technologies, and trained workers, several facilities find it challenging to put aside enough money for successful WM (Gahlot et al., 2019; Sharma et al., 2020).

52.6.7 Illegal Dumping and Improper Disposal

The greater amount of BW brought on by the epidemic has increased the risk of illegal dumping and improper disposal. Due to poor infrastructure, a lack of understanding, or restricted access to suitable waste disposal facilities, some people or healthcare organizations may resort to criminal practices, including dumping trash in public areas, bodies of water, or common waste streams. This not only endangers the environment and the health of the general population, but it also promotes the spread of diseases (Sharma et al., 2020; Subramanian et al., 2021).

52.6.8 Regulation Compliance

During the COVID-19 pandemic, adherence to regulations and standards for BMW is crucial. The dynamic and fast-evolving nature of the pandemic, however, can make it challenging for medical facilities to stay on top of the new regulations and ensure strict adherence. Adequate monitoring and enforcement are needed to ensure adherence to WM regulations and protect against any mistakes (Gahlot et al., 2019; Sharma et al., 2020).

To solve these problems, multiple groups must cooperate. The construction of specialized treatment facilities, the improvement of WM infrastructure, and ensuring regulatory compliance should all be funded by governments and healthcare companies. Healthcare facilities, particularly those located in underdeveloped areas, may receive financial support and incentives to help them set up effective WM practices. Awareness campaigns and training programs should be implemented to better educate healthcare workers, waste handlers, and the general public on the importance of safe

BMW and related procedures. Rules should be carefully enforced, and there should be consequences for illegal dumping to deter improper disposal methods (Das et al., 2020; Gahlot et al., 2019; Subramanian et al., 2021).

52.7 Conclusion and Future Prospects

BMW is now being taken seriously by the majority of healthcare establishments. All healthcare practitioners are required to understand the handling, processing, and transportation of hospital waste as well as how to appropriately dispose of it.

A long-term solid waste management plan focuses on implementing a constant shiftable work routine to minimize worker's exposure to toxic medical waste and the plan must also focus on repurposing the waste to reduce the amount of BMW disposed of. For example, reusable masks can be disinfected and repurposed. Additionally, the plant must be developed quickly, because the COVID-19 outbreak is expected to endure until 2025. There needs to be a broad awareness among the population to handle the present scenario effectively. The sources of garbage and the disposal techniques employed include household waste, COVID-19 quarantine centers, hospitals, source segregation, recyclable waste, residual waste, biohazard waste packaging, conventional packaging, or paper bags can be used as packaging material. It is advisable to double bag your waste in disposable bags because the COVID-19 virus has a shorter life span than the ones on plastics.

The current chapter emphasized how crucial it is to see BMW management as an opportunity to employ sustainable solutions such as it is used in agriculture as fertilizer, in energy generation as biogas, biofuel, electricity generation, etc., and in manufacturing and construction materials like cement. By exploiting the potential of BMW, we may overcome the challenges and contribute to the development of a more sustainable future. By converting the issues caused by BMW into possibilities, we can safeguard human health, safeguard the environment, and pave the way for a more sustainable and resilient future.

The COVID-19 outbreak has had a considerable impact on the way solid waste is currently managed. The harmful consequences of the pandemic should be minimized by utilizing decentralized waste management and its integration (Hantoko et al., 2021).

- Follow the instructions to clean the disposal bag, give the trash at least 72 h to rest before final disposal, and take other waste-reduction efforts.
- Management of plastic trash at the source is advised to reduce footprints left by plastic garbage. Although it will cost more, switching from plastic derived from fossil fuels to bioplastics can be sustainable.
- Nations have developed rigorous yet flexible waste disposal regulations to stop the spread of viruses through solid waste produced by residences, hospitals, and COVID-19 patients who are self-isolated (Tripathi et al., 2020).

- Effective BMW management practices must consider novel technology like artificial intelligence and robotics applications, and they must be put into practice in emerging nations (Subramanian et al., 2021).

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Chapter 16
Production of Biodiesel from Waste Cooking Oil

Vishal Vasistha, Suraj Bhan, K. Rajagopal, and C. Obula Reddy

Abstract The overconsumption of conventional petroleum fuels contributes to the faster depletion of existing fuel reserves and a substantial price hike in petroleum crude oil prices. Thus, there is a solid demand to identify sustainable and adequate alternatives for traditional ongoing conventional petroleum-based fuels. The selection of a suitable alternative energy depends on its ready availability, renewability, and lowering pollution. Biodiesel has attracted immense popularity among renewable fuels due to its environment-friendly and non-toxic characteristics. Biodiesel is manufactured utilizing different types of feedstock, catalysts, and technologies. A feedstock that is waste could be a superior choice to produce biodiesel. Therefore, the authors have chosen waste cooking oil as feedstock to review in this book chapter. This review systematically investigates biodiesel production from different kinds of waste cooking oils. Further, it provides detailed knowledge of various methodologies to prepare waste cooking oil-based biodiesel, the addition of several nanocatalysts, the advantages and disadvantages of using this particular feedstock, and recent trends and challenges in this field.

Keywords Waste cooking oil · Biodiesel · Transesterification · Renewable fuel

V. Vasistha (✉) · S. Bhan
Department of Mechanical Engineering, School of Engineering and Technology, Noida International University, Greater Noida, Uttar Pradesh, India
e-mail: vishal.vasistha@niu.edu.in

K. Rajagopal
Department of Physics, Chaitanya Bharathi Institute of Technology, Kokapet, Hyderabad, Telangana 500075, India
e-mail: krajagopal_biotech@cbit.ac.in

C. O. Reddy
Department of Biotechnology, Chaitanya Bharathi Institute of Technology, Kokapet, Hyderabad, Telangana 500075, India
e-mail: cobulreddy_biotech@cbit.ac.in

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16.1 Introduction

Biodiesel is an inexhaustible, biodegradable, and environmentally friendly fuel procured from vegetable oils of various types or fats of different kinds of animals used in compression ignition engines. Biodiesel retains its popularity in energy security, energy diversity, environmental advantages, sustainable agriculture, and economic development (Bhan et al., 2022a). The production of biodiesel can reduce dependence on imported fossil fuels, providing countries with greater energy security and reducing the risks associated with fluctuating oil prices and supply disruptions. It has the potency to lower greenhouse gases (GHGs) emitted and air pollution along with its associated health risks, improve air quality and mitigate the negative impact of transportation on the environment (Vasistha & Bharj, 2019). Several raw materials can manufacture biodiesel as a fuel source, including algae, waste oils, soybeans, rapeseed, and other oil-producing crops, which can help promote sustainable agriculture practices and reduce the environmental impact of farming. Biodiesel could promote sustainable agriculture practices and reduce the environmental impact of farming (Ambat et al., 2018). Biodiesel production can create jobs and stimulate local economies, especially in rural areas where farming and agriculture are the primary industries. It can also help reduce trade deficits by providing a domestic alternative to imported petroleum, which helps to broaden the energy supply and reduce reliance on a single fuel source. Higher cetane ratings in biodiesel can enhance engine performance and reduce wear and tear. Additionally, it has more lubricity, which can lessen the chance of engine damage. Biodiesel is used in diesel engines and infrastructure with little to no change to minimize emissions and improve energy security.

The International Energy Agency (IEA) estimates that in 2019, diesel accounted for almost 20% of all energy-related CO_2 emissions worldwide, which makes it a significant contributor to climate change. However, diesel consumption has declined in many regions due to the growing popularity of electric vehicles and stricter emissions regulations. In 2019 China, the United States, India, and Russia were the largest diesel consumers. However, the COVID-19 pandemic in 2019–2020 substantially decreased diesel demand, particularly in the transportation and industrial sectors (Suzihaque et al., 2022). According to the IEA, diesel usage will continue to decrease over the next few years as countries transition towards cleaner forms of energy (Fig. 16.1). However, diesel will still be essential in heavy-duty transportation and specific industrial sectors, such as construction and mining.

Production of Biodiesel takes place through several methods. The most popular technique for producing biodiesel is transesterification, which involves combining vegetable oil or animal fats with an alcohol, usually methanol or ethanol, and a catalyst, commonly sodium or potassium hydroxide. This process breaks down the triglycerides in the oil or fat into fatty acid methyl esters (FAMEs), separated from the glycerol byproduct (Bhan et al., 2022b). Pyrolysis is another way the feedstock is fired up without oxygen to break down the long-chain hydrocarbons into shorter hydrocarbons. Usually, low-quality feedstocks like leftover cooking oil or animal fats are used in this procedure. The feedstock is combined with methanol in the

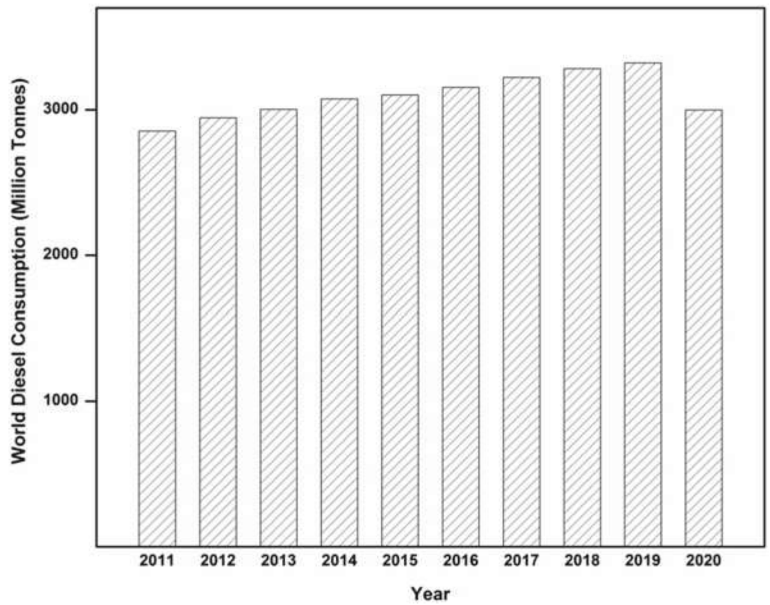

Fig. 16.1 World diesel consumption in recent years

supercritical methanol technique at high pressure and temperature, which induces a supercritical state that splits long-chain hydrocarbons into FAMEs. This process is more energy-intensive than transesterification. The enzymatic Transesterification process uses enzymes as catalysts instead of traditional catalysts, which can reduce the energy required and produce higher-quality biodiesel. The microbial Fermentation approach utilizes microorganisms (bacteria/yeast) to break down the feedstock into fatty acids, which are then converted into FAMEs through transesterification. The feedstock used, the volume of production, and the required quality and purity of the finished product all influence the type of biodiesel production.

WCO is a byproduct of the food industry and is often discarded in landfills or disposed of improperly, leading to soil contamination and water spoiling. Reducing trash generation, supplying a sustainable energy source, and lowering greenhouse gas emissions are just a few advantages of using waste cooking oil to make Biodiesel (Omar & Amin, 2011). Additionally, biodiesel created from WCO is a potential substitute for conventional diesel fuel because it can be utilized in diesel engines without any modification.

16.2 Waste Cooking Oil as Feedstock for Biodiesel Production

Waste cooking oil (WCO) describes cooking oils and fats used for cooking or frying but is no longer suitable for their original purpose. It results from numerous culinary operations in kitchens, dining establishments, and food processing facilities. After cooking, waste cooking oil becomes contaminated with food particles, moisture, and impurities. It may also undergo chemical changes due to exposure to high temperatures, affecting its quality and nutritional properties. It is, therefore, no longer fit for ingestion and is regarded as garbage (Gnanaprakasam et al., 2013). However, waste cooking oil can be recycled and repurposed through oil reclamation or used cooking oil recycling. It involves filtering and purifying the oil to remove impurities, food particles, and moisture. Recycled cooking oil can be used in various applications, such as biodiesel production, animal feed additives, industrial processes, and even certain cosmetics and soaps. Recycling waste cooking oil is an environmentally friendly practice as it helps reduce the amount of oil waste that ends up in landfills or pollutes water sources. Proper disposal and recycling of waste cooking oil are essential to prevent environmental contamination and promote sustainable resource management.

Improper disposal and reuse of waste cooking oil can have negative health consequences. Over time, waste cooking oil can undergo oxidation and become rancid. Rancid oil contains harmful compounds that can adversely affect health if consumed. Consumption of contaminated oil may lead to food-borne illnesses and gastrointestinal problems. Trans fats can occur when cooking oil is used often and at high temperatures. Heart disease risk is known to be elevated by trans fats. Reusing cooking oil for deep frying can contribute to the formation of acrylamide, a potentially carcinogenic compound. Regularly consuming foods prepared in waste cooking oil with high acrylamide levels may increase the risk of certain cancers (Degfie et al., 2019).

The primary sources of WCO production are households, restaurants, cafes, the food service industry, food processing and manufacturing companies, institutions such as schools, hospitals, prisons, and the military, and fast food chains and franchises. The scale of WCO production can vary significantly by region, population density, cultural dietary practices, and the scale of food-related industries in a particular area. Efforts to collect and recycle waste cooking oil have been increasing globally to mitigate environmental impacts and promote sustainable practices, including its conversion into biodiesel or other valuable products (Park et al., 2019).

The physicochemical properties of WCO could vary depending on factors such as the type of oil, duration of use, exposure to high temperatures, processing methods, and level of contamination (Raqeeb & Bhargavi, 2015). It is typically a liquid with a translucent to opaque appearance. It can range in color from golden yellow to brown. WCO has a relatively higher viscosity and lower density compared to water. WCO may have an elevated level of free fatty acids (FFA) due to the hydrolysis of triglycerides during degradation. Higher FFA content indicates a lower quality of oil.

Waste cooking oil with a higher peroxide value and a lower smoke point indicates more significant oxidative degradation and rancidity.

Compared to other types of oils, WCO is cost-effective and abundantly available as a byproduct of culinary practices in households, restaurants, and food processing industries. This availability makes it a potential resource for recycling and repurposing, reducing reliance on virgin oils. Recycling WCO for biodiesel production can contribute to energy savings. WCO Biodiesel has a lower energy-intensive production process than soybean or palm biodiesel.

16.3 Formulation of Biodiesel from WCO

Transesterification converts lipids or vegetable oils into FAME and glycerol at a specified temperature while also requiring a catalyst, a certain amount of alcohol, and other conditions. It is also known as the alcoholysis process (Enweremadu & Mbarawa, 2009). One mole of glycerol and three moles of esters were produced by a reaction between one mole of triglycerides and three moles of alcohol (Zou et al., 2013). Transesterification of fats or vegetable/waste oils produces biodiesel. To produce a higher production of biodiesel, high alcohol content is desired (Agarwal, 2007). The choice of catalysts is vital because the reaction produces more soap if a suitable catalyst with a certain quantity is not employed. Different kinds of catalysts, including acid, base, enzyme, and nanocatalysts, can be utilized in this process. Catalysts for the reactions of acids and bases (alkalis) can be homogeneous or heterogeneous. Due to their higher product yield, alkali catalysts are preferable. Due to its lower price, methanol is chosen over other alcohols for transesterification reactions. The transesterification procedure is relatively straightforward and affordable, which accounts for its widespread use. Figure 16.2 depicts the conceptual structure of the transesterification process used to produce Biodiesel from WCO.

Waste oil produced by the food processing sector is sent straight to the biodiesel facilities. In other circumstances, the same industry uses cooking oil to make biodiesel and uses the fuel to power its plant equipment. Local collection companies gather the used cooking oils produced by fast food restaurants or other eateries. The waste oil is supplied to the biodiesel processing businesses through neighborhood collection services or factories, either with or without pre-treatment. The first stage in the biodiesel processing business is to evaluate the WCO's quality. The recommended oil is processed further for biodiesel creation following the quality inspection.

Filtered waste cooking oil is used for cooking in order to get rid of a range of cooking residues from cafeterias and restaurants. Because waste cooking oil is more dense and viscous than diesel fuel, it may not be easy to atomize and introduce fuel into the combustion chamber. The transesterification process was picked to create the biodiesel. In order to remove moisture, raw WCO is heated to 100 °C in a beaker before being cooled to 60 °C for transesterification. The reaction flask is heated to a temperature between 60 and 70 °C and spun at 400 rpm. The entire process took two hours to settle down. Biodiesel is made from it because it has a higher density

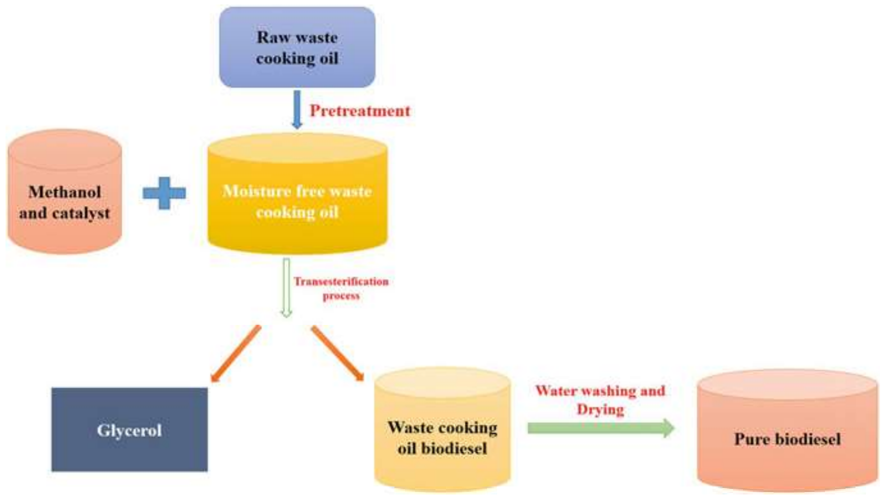

Fig. 16.2 Process of biofuel production

than glycerol. The biodiesel is then washed with warm water heated to between 80 and 90 degrees Celsius in the following step. A thick fat residue would be removed and settled down by heated water.

Further, biodiesel is cooked one more to 100 °C in order to eliminate moisture. Using this process, biodiesel is created without the use of moisture or residuals. Then, a sample of pure WCO biodiesel is made (Bhan et al., 2022b).

Freedman and his team carried out a transesterification reaction at 65 °C for 4140 min using homogeneous H_2SO_4 and methanol (30:1), and 99% biodiesel was produced (Freedman et al., 1984). Alcohol is needed in large quantities when an acid catalyst is used (Leung et al., 2010). This experiment produced a large amount of biodiesel (99%) thanks to a high homogenous H_2SO_4 catalyst concentration (41.8% by weight) and a high molar methanol to oil ratio (245:1). Numerous investigations have shown that for homogeneous acid-catalyzed transesterification reactions under conditions of moderate temperature, the reaction time decreases as the quantity of alcohol increases. H_2SO_4 is the most widely used homogeneous acid catalyst because of its low cost, high reactivity, and high biodiesel yield. For waste oils with a high FFA level, heterogeneous acid catalysts are advised above homogeneous acid catalysts.

The highest biodiesel generation (98.2%) from WCO is achieved when a homogeneous KOH catalyst is used. The study employed a homogeneous KOH catalyst at a concentration of 1% (w/w) and a molar alcohol-to-oil ratio of 6:1. The entire conversion of triglycerides to FAMEs occurs in 60 min at a temperature of 70 °C (Agarwal et al., 2012). A different experiment shows that when KOH, methanol, reaction duration, and reaction temperature increase, biodiesel yields less (87%).

Felizardo's research team reported high biodiesel production (98%) in 40 min at 65 °C temperature utilizing 0.6% (w/w) of NaOH catalyst and little alcohol (4.8:1) content (Felizardo et al., 2006). These studies demonstrate that biodiesel production is reduced when catalyst concentration, reaction temperature, or methanol to oil molar ratio increases over their optimum values. In addition to requiring more alcohol than homogeneous catalysts, heterogeneous base catalysts also have slower reaction rates.

16.4 Physicochemical Properties of WCO

Due to its abundance, low cost, and positive environmental effects, waste cooking oil (WCO) has drawn much attention as a potential feedstock for the generation of biofuels. WCO's composition and impurity content impact its physiochemical characteristics as a biofuel. The following are some significant physiochemical characteristics of used cooking oil as a biofuel:

Fatty Acid Composition: The main component of used cooking oil is triglycerides, which are fatty acid esters. Depending on the cooking oil used and the degree of use-related deterioration, WCO's fatty acid composition can change. Oleic, linoleic, and palmitic acids are typical fatty acids in WCO. The WCO-based biodiesel's fatty acid profile affects the fuel's viscosity, oxidative stability, and cold flow characteristics.

Viscosity: The viscosity of WCO-based biodiesel is an important property that affects fuel atomization, combustion efficiency, and overall engine performance. Typically, used cooking oil has a higher viscosity than regular diesel fuel. However, through the transesterification procedure, WCO can be transformed into biodiesel, which typically has a lower viscosity and is comparable to diesel fuel. This transformation improves fuel flow characteristics and ensures compatibility with diesel engines.

Density: WCO-based biodiesel's density is slightly lower than petroleum diesel's. This lower density can contribute to improved fuel economy due to reduced weight. However, it may also result in a decrease in energy content per volume.

Flash Point: WCO-based biodiesel often has a higher flash point than petroleum diesel. The fuel is safer because of its higher flash point, which lowers the possibility of accidental fire. The flash point may change depending on the specific fatty acid content and contaminants in the used cooking oil; it is crucial to remember.

Cetane Number: The ignition quality of gasoline is indicated by the cetane number. Higher cetane levels indicate better ignition properties. Compared to petroleum diesel, waste cooking oil-based biodiesel has a higher cetane number, improving combustion efficiency and lowering emissions.

Oxidative Stability: Waste cooking oil contains some oxidation products and impurities resulting from its previous use in cooking. These impurities can negatively impact the oxidative stability of the resulting biodiesel. It is essential to properly treat and purify the WCO before transesterification to minimize the presence of impurities and ensure good oxidative stability.

Cold Flow Properties: Biodiesel from used cooking oil typically has a higher cloud and pour point than regular diesel fuel. The cloud point is known as the temperature at which crystals start to form and cause the fuel to appear foggy. The lowest temperature fuel can still flow is known as the pour point. These properties can impact the usability

Table 16.1 Physicochemical properties of different biodiesels

Oil	Dynamic viscosity (kg/m^3) at 40 °C	Kinematic viscosity (mm^2/s) at 40 °C	Density (kg/m^3)	High calorific value (kJ/kg)	References
WCME (50% WCPM + 50% WCSM)	3.7978	4.3984	0.8635	39876	Bhan et al. (2022b)
D100	0.8107	1.8845	2.3244	42875	Bhan et al. (2022b)
Sunflower oil	–	4.13	0.869	40600	Singh et al. (2019)
Jatropha	–	4.80	0.880	40790	(Singh & Singh, 2010; Singh et al., 2019)
Coconut	–	3.13	0.867	38200	Singh et al. (2019)
Mustard	–	5.53	0.889	41910	(Sarin et al., 2007; Singh et al., 2019)

of WCO-based biodiesel in colder climates and may require additives or blending with conventional diesel to improve cold flow characteristics.

Impurities: Waste cooking oil can contain various impurities, such as water, free fatty acids, and particulate matter. These impurities can negatively impact the resulting biodiesel's fuel properties, stability, and performance. Adequate pre-treatment and purification processes, such as water removal, acid esterification, and filtration, are necessary to reduce impurities and enhance biofuel quality.

It is worth noting that the physiochemical properties of WCO-based biodiesel can vary depending on the specific source and processing techniques employed. Proper quality control measures and adherence to biodiesel standards are crucial to ensure consistent fuel properties and optimal performance. The physiochemical properties of various oils are given in Table 16.1. It was found that these physiochemical properties are similar to the diesel engine. That is why waste cooking oil may be used as an alternative fuel without a change in the design of diesel engines.

16.5 Study of WCO Biodiesel Transesterification Process

Various experimental procedures are available to generate biodiesel. Transesterification is the famous regular method (Sharma & Singh, 2008). The method's main advantages are high yield and low cost (Atabani et al., 2012).

Homogeneous and heterogeneous catalyzed reactions are fundamentally the two types of possible transesterification processes (Fernando et al., 2018). Essentially, a transesterification reaction can be initiated in an acid catalyst, alkali, or base catalyst. Since the base-catalyzed transesterification method is more efficient and affordable than the acid-catalyzed transesterification process, it has gained popularity (Demirbas, 2009). However, the presence of FFA hinders the transesterification process as the reaction of the base catalyst with FFA produces an unwanted soap (Patil et al., 2010).

WCO has a high water content and is rich in free fatty acids (FFA). Triglycerides in WCO can hydrolyze in the water to become FFA. FFA reacts with a base catalyst in a saponification reaction to make soap in a base-catalyzed transesterification process. In Eq. 16.1, the reaction is depicted. Therefore, the catalyst and ester quantities will likely be lost in these chemical reactions. As a result, it raises the price of producing WCO-based Biodiesel (Dang et al., 2019a). Therefore, WCO must undergo pre-treatment to reduce FFA content within the recommended level of lower than 1% (by weight) before the base-catalyzed transesterification process (Dang et al., 2019b).

$$\mathrm{RCOOH(FFA)} + \mathrm{NaOH} \rightarrow \mathrm{RCOONa(SOAP)} + \mathrm{H_2O} \tag{16.1}$$

As part of the pre-treatment procedure, FFA is esterified with alcohol while exposed to sulfuric acid. Sulfuric acid serves as a homogenous acid catalyst in the reaction. In Eq. 16.2, the reaction is depicted.

$$\mathrm{RCOOH} + \mathrm{R'OH} \xleftrightarrow{\mathrm{H_2SO_4}} \mathrm{RCOOR'} + \mathrm{H_2O} \tag{16.2}$$

Commercial biodiesel synthesis uses alkaline catalysts because they are less corrosive to industrial machinery than acid catalysts. The transesterification reaction typically occurs when methanol and vegetable or animal fat are mixed in a 1:6 molar ratio, with NaOH as a catalyst. It is a three-step process in which the first, second, and third stages involve the conversion of TG (Triacyl Glycerol) to DG (Diacyl Glycerol), DG to MG (Monoacyl Glycerol) and G (Glycerol), as shown in Eq. 16.3 (Fernando et al., 2018).

$$\left.\begin{array}{c}\mathrm{TG} + \mathrm{M} \leftrightarrow \mathrm{DG} + \mathrm{ME} \\ \mathrm{DG} + \mathrm{M} \leftrightarrow \mathrm{MG} + \mathrm{ME} \\ \mathrm{MG} + \mathrm{M} \leftrightarrow \mathrm{G} + \mathrm{ME}\end{array}\right\} \tag{16.3}$$

For direct usage in diesel engines, the transesterification reaction's primary goal is to lower the oil's high viscosity (Rajagopal et al., 2022). Fatty Acid Methyl Esters (FAME) are created during the general transesterification process when TG in the oil combines with the short-chain alcohol methanol. Glycerol is removed from TG during the process, and the methyl (CH_3) group replaces it to complete the transesterification (Moser, 2009). Figure 16.3 depicts the transesterification procedure (Rajagopal et al., 2022).

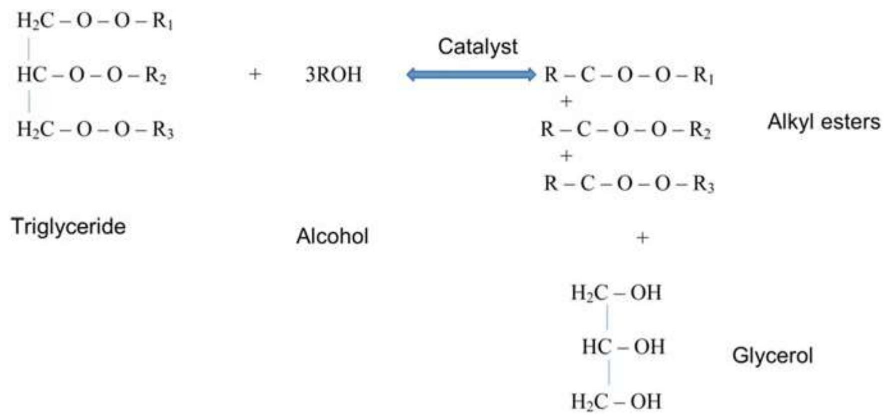

Fig. 16.3 The transesterification of triglyceride with methanol in the presence of a catalyst

16.5.1 Effect of Reaction Temperature

Transesterification is an endothermic process; hence the amount of biodiesel produced is influenced by the reaction's temperature (Baskar et al., 2018). It is due to a decrease in oil viscosity, which improves reactant mixing and raises the generation of Biodiesel (Takase et al., 2014). To prevent methanol from vaporizing, the reaction temperature is typically adjusted below that of methanol (Encinar et al., 2016; Leung et al., 2010). The ideal temperature for fresh, unused oil feedstock for biodiesel manufacturing is 60 °C. The ideal temperature for the transesterification reaction in WCO with high FFA concentration is 75 °C (Al-Saadi et al., 2020), while for WCO with low FFA content, it is 65 °C (Farooq et al., 2015).

16.5.2 Effect of Reaction Time

The generation of biodiesel rises as the response time rises (Leung et al., 2010). The characteristics of the catalyst and feedstock affect the reaction time. According to Salem and teammates (Salam et al., 2016), the alkaline-catalyzed transesterification reaction proceeds 4000 times faster than the base-catalyzed reaction. For an alkaline-catalyzed transesterification reaction, the maximum generation of biodiesel happens in 90 min (Leung et al., 2010). During the acid-catalyzed transesterification process, it takes several hours to complete the reaction (Freedman et al., 1986). In the case of WCO with high content of FFA, transesterification takes place for 5 h for the maximum yield of Biodiesel (Al-Saadi et al., 2020), and in the case of low FFA content, it is 4 h (Farooq et al., 2015).

16.5.3 Effect of Catalyst

The type of catalyst used during the transesterification reaction is one-factor influencing biodiesel production. Both the amount and quality of biodiesel production are impacted. The transesterification process is accelerated by applying either chemical or biological catalysts. Homogeneous (alkaline or acid) and heterogeneous (alkaline or acid) based catalysts can be used as chemical catalysts. Homogeneous alkaline catalysts are frequently employed for their benefits, including good selectivity and high transesterification reaction rates (Baskar et al., 2019). The merit of the heterogeneous catalyst is that the biodiesel produced will be free from catalysts used and ensures high-quality biodiesel (Pamilia et al., 2019). In the latest trend, heterogeneous nanocatalysts and supercritical fluids generate quality end products with an effective transesterification process in less time. Biological catalysts are enzymes such as immobilized lipases. The main advantage of biological catalysts is that they are environmentally friendly. However, these are costly. The classification of catalysts is shown in Fig. 16.4 (Baskar et al., 2019).

For the best production of biodiesel, homogenous alkaline catalysts are typically utilized. Among the alkaline catalysts available (CH_3ONa, NaOH, and KOH), higher biodiesel production is possible with Sodium Methoxide (CH_3ONa) as the catalyst for fresh oil feedstock (Rosaura et al., 2009).

Recently, biodiesel has been produced from WCO using egg shell derived Calcium Oxide (CaO) nanocatalyst. It was a low-cost and environmentally friendly approach for generating Biodiesel from WCO (Erchamo et al., 2021).

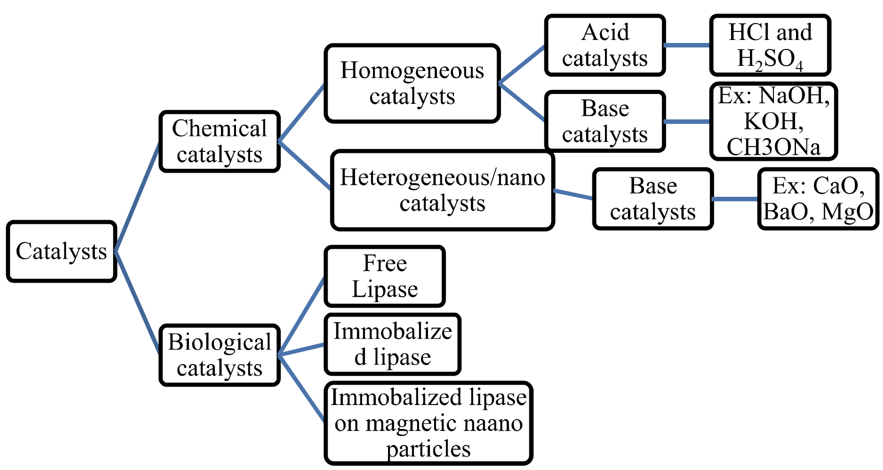

Fig. 16.4 Classification of catalysts in the transesterification process

16.5.4 Effect of Alcohol-to-Oil Ratio

The ratio of alcohol to oil is crucial in the creation of biodiesel. It is possible to employ alcohols such as methanol, ethanol, pentanol, and butanol (Nasar et al., 2018). Because it is less expensive than other alcohols, methanol is typically utilized for the industrial synthesis of Biodiesel (Van Gerpen, 2005). More methanol is used in the acid-catalyzed transesterification reaction, which also needs a 1:15 oil-to-methanol ratio. In contrast, a base-catalyzed process only needs a 1:6 oil-to-methanol ratio and uses less alcohol than an acid catalyst (Leung et al., 2010).

Using insufficient and excess amounts of methanol leads to poor biodiesel production. Suppose the methanol is less than required for the transesterification reaction. In that case, biodiesel will not be produced, and the reaction will be reversed as the transesterification process is reversible. If more than required, excess methanol must be removed from the final product (Reddy et al., 2017). To produce biodiesel from the transesterification of WCO (with low FFA) with ethanol requires a 1:10 oil-to-alcohol ratio; methanol is 1:15 (Farooq et al., 2015).

16.6 Advantages and Disadvantages Associated with WCO Biodiesel

16.6.1 Advantages of Waste Cooking Oil Biodiesel

Food safety: Biodiesel production has been taking place over a long period. As it is renewable and environmentally friendly, it has attained focus. Concerns about biofuel's impact on land utilization and food costs have been raised in the meantime due to the noticeably rising prices of crops. When WCO is used to produce biodiesel, pressure on food crops to provide biofuel will be released. EU nations produce between 0.7 and 1 million tonnes of WCO annually, the UK produces 0.2 million tonnes, and Canada produces 0.135 million tonnes. According to Sani et al. (2013), China and Japan produce 4.5 and 0.6 million tonnes of WCO annually. Having adequate production, it is possible to ensure food safety.

Energy safety: According to the International Energy Outlook 2017, global energy consumption will increase by 28% between 2015 and 2040, with non-OECD Asia accounting for more than half of the increases because of the region's robust economic growth. The usage of fossil fuels results in the release of greenhouse gases and is not renewable. Now is the time to replace fossil fuels with renewable energy sources. As long as WCO is available and energy security can be obtained; biodiesel can be produced because it is renewable. Globally, more biodiesel made from WCO is being produced. In Europe, 800-kilo tonnes of WCO were produced in 2011, but 1800 000 tonnes were produced in 2014 (Ahmad et al., 2014). According to Omar and Amin (2011), recycled grease comprised about 13% of the total feedstock used to make biodiesel in the US in 2016.

Environment friendly: Between 2015 and 2040, it is predicted that carbon dioxide (CO_2) emissions related to global energy will rise by an average of 0.6% annually. According to studies, biodiesel emits carbon dioxide at a considerably smaller scale than petroleum diesel, emitting 48% less CO, 47% less particulate matter, 67% fewer HCs, and very little unburned hydrocarbons (Huiming et al., 2014). Therefore, using WCO to produce biodiesel increases its life cycle and benefits the environment as it is renewable, non-toxic, and has low emissions. Even Biodiesel from WCO prevents underground water, soil, and sewerage system pollution. The use of WCO biodiesel reduced emissions of carbon monoxide (CO), hydrocarbons (HC), and particulate matter (PM), according to several studies (Datta & Mandal, 2016; Elisa et al., 2016).

Creation of direct and indirect jobs: The World Bank states that the companies that create biofuels need around 100 times more people per unit of energy produced than the industries that produce conventional fuels (Caldeira et al., 2016). Because of the biofuel industry, employment grew by about 3% to an estimated 1.7 million in 2016 (Zhang et al., 2003). At every stage of the manufacture of biodiesel, jobs can be created. People are required for transport and raw material storage in the fuel supply chain. Jobs in the equipment installation, operation, and routine maintenance sectors are available in the energy sector.

Waste cooking oil is cheaper than pure vegetable oil, drawing attention as an excellent alternative to produce biodiesel. WCO is a prominent source of biodiesel production, particularly in remote areas with a shortage of regular fuel supply facilities. For many WCO collectors in the biodiesel supply chain, WCO collection points toward additional income. Many works about WCO collection using community collectors (Elisa et al., 2016; Fu et al., 2005; Yaakob et al., 2013; Zhang et al., 2003) also mention poverty eradication by income generation for a low-skilled population. WCO biodiesel has a low sulfur level, is non-toxic, and is biodegradable. It can be utilized in CI engines with a few modest adjustments. One of the critical merits of Biodiesel from WCO is its contribution to the circular economy.

16.6.2 Disadvantages of Waste Cooking Oil Biodiesel

The pre-treatment setup used in the alkali catalyst approach results in a reasonably sophisticated process that uses much equipment to reduce the amount of FFA. The reaction results in soap and water if the FFA concentration exceeds 3 wt% (Caldeira et al., 2016). A pre-treatment is necessary before the transesterification procedure to minimize the quantity of free fatty acid because of the delicate nature of the alkali-catalyzed reaction to FFA (Fu et al., 2005). Solid wastes need to be removed after the pre-treatment phases. However, the amount of FFA and water must be decreased (Huiming et al., 2014; Zhang et al., 2015).

The production of biodiesel depends heavily on the WCO recovery rate. Low recovery rates result in a lack of feedstocks. This will deter biodiesel businesses and prevent large amounts of biodiesel manufacturing. China can produce between 4 and 8 million tonnes of WCO annually. This quantity can be collected in half. However, China's recovery rate is still low at the right moment. The recovery rate is much lower than 50% in Beijing and Nanjing (Kulkarni & Dalai, 2006).

Additionally, Singapore's WCO recovery rate is lower. In 2010, the Agrifood & Veterinary Authority (AVA) of Singapore reported that 115,585 tonnes of oil were consumed, with just a tiny portion recycled into biodiesel. Most of it revolves around the process of preparing meals (Dogan, 2016). According to Talebian-Kiakalaieh and his colleague (Talebian-Kiakalaieh & Amin, 2013), WCO barely accounted for 0.5% of the biodiesel produced in Brazil in 2015.

After continuous use, the WCO raw material develops issues, including increased sourness, blackness, and unpleasant odor. The cost of purifying WCO reduces its economic benefit as a source of raw materials for biodiesel manufacturing (Sze-Wee et al., 2014). The WCO's quality significantly impacts the production of biodiesel. The physical qualities of biodiesel greatly vary depending on the amount of salt, cooking duration, and water used. As a result, no kind of WCO may be utilized to make biodiesel. Therefore, a thorough investigation of its defining characteristics is required. The transesterification reaction process needs to be revised due to the water concentration in WCO.

16.7 Competitiveness of WCO Biodiesel with Diesel

Food security is threatened by biodiesel production from edible oil sources, and land acquisition for cropland is threatened by production from non-edible sources. WCO is a suitable feedstock for synthesizing biodiesel due to the availability of various fatty acids (Priyanka et al., 2021). The main advantage of biodiesel production from WCO is its cheaper cost than any other feedstock, and it is sourced from waste. However, it has the disadvantage of the added pre-treatment process because of having FFA and water (Suzihaque et al., 2022). To overcome this, there have been investigations, such as using nanocatalysts and the mixture of methanol-ethanol in the transesterification process. One such study was reported with an eggshell-derived nano CaO catalyst with a methanol-ethanol mixture and obtained enhanced biodiesel production yield of around 90% conversion of WCO collected from restaurants which are a mixture of palm and sunflower oils. The produced biodiesel even met the ASTM D6571 biodiesel standards (Erchamo et al., 2021). In another study using nano Zn-CaO catalyst with the help of response surface methodology, the biodiesel conversion rate of WCO is increased to 96.5%, which is in agreement with the ASTM6571 biodiesel standard (Weldeslase et al., 2023).

16.8 Conclusion and Future Scope

Biodiesel has become the most attractive substitute for conventional petroleum fuels due to its biodegradable, economical, non-toxic, and abundant local and renewable characteristics. WCO has considerable potential to be used as a biodiesel feedstock because of its abundance worldwide and comparatively lower cost than other raw materials. It could play a crucial and significant role in the future Biodiesel manufacturing industry. Besides this, WCO requires many pre-treatment processes to discard solid non-usable residues and lower water quantity and FFA content. In WCO biodiesel synthesis, the transesterification method is affected by factors like reaction temperature and time, catalyst quantity, and alcohol-to-oil ratio. WCO biodiesel has many advantages over diesel in terms of food, energy safety, and environmental cleanness. Besides this, it utilizes waste material into usable fuel, which improves engine performance and reduces emissions.

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Chapter 37
Effective Utilization of Tannery Waste for the Fabrication of Construction Materials

Chittepu Obula Reddy, Sharvani Pokala, Spoorthi Sada, and Bhavani Pokala

Abstract The tannery is a well-established, age-old industry that has been substantially industrialized across all nations over time and contributes significantly to the global economy, but it also offers a serious threat to the environment due to its high water and more than 250 chemicals, including polychlorinated biphenyl, chromium, sulfides, nitrates, and others, are utilized in the process, which results in the production of effluent with a high concentration of pollutants into the ecosystem. The ecosystem is severely impacted by a large-scale discharge of inadequately handled solid tannery waste (STW), which contaminates the soil, surface water, and groundwater resources and poses serious risks to human and animal health. Proteinaceous untanned and tanned waste make up STW, which must be properly treated for disposal in an environmentally friendly manner. Over the years, a number of strategies have been created STW should be reduced and recycled to produce renewable energy (biogas and biohydrogen), biofuels (biodiesel and briquettes), building materials, fertilizers, commercial items (adsorbents, animal feeds, proteins, fats, and enzymes), biodegradable packaging and non-packaging materials, and biodegradable packaging and non-packaging materials. In this book chapter, we will emphasize the utilization of solid tannery waste (STW) as useful construction material. A brief review of both traditional and modern methods for treating tannery industry effluent also covered the role of nanotechnology in the tannery industry. We can protect the ecology, aquatic wildlife, and human health by turning the problem created by solid tannery waste into a possibility, paving the path for a healthier and more sustainable future.

C. O. Reddy · S. Pokala (✉) · S. Sada
Department of Biotechnology, Chaitanya Bharathi Institute of Technology, Hyderabad, Telangana 500075, India
e-mail: sharvanipokala@gmail.com

C. O. Reddy
e-mail: cobulreddy_biotech@cbit.ac.in

B. Pokala
Department of Chemical Engineering, Chaitanya Bharathi Institute of Technology, Hyderabad, Telangana 500075, India

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Keywords Solid tannery waste (STW) · Hybrid technology · Adsorbents · Biofuels · Enzymes

37.1 Introduction

Tannery operations mainly focus on the production of leather and related products, transforming animal skins and hides through a series of stages to create leather. This tanning procedure involves various chemicals such as sodium sulfide, lime, ammonium sulfate, vegetable tannins, sodium chloride, chromium salts, and bactericides, as well as a significant quantity of water. Nonetheless, traditional tanning methods pose a significant threat to the environment due to the generation of chemical and organic pollutants. These hazardous substances are commonly found in discharged effluent and thus represent a substantial ecological concern (Patel et al., 2021).

Tannery effluent is a complex mixture of organic and inorganic components from many operations. If not treated before being disposed of, this effluent can lead to severe contamination of the environment, particularly aquatic bodies. Tanning businesses utilize a variety of chemicals in various unit processes ranging from preservation to completed leather goods. Complex mixes of organic and inorganic compounds with high concentrations of Cr, BOD, COD, TDS, intense color, and pH characterize tannery effluent (Alemu et al., 2021).

The vast number of dangerous chemicals present in tannery effluents have been shown to have devastating effects on water bodies, soil quality, and air quality, with significant negative consequences for both humans and other living organisms (Sivaram & Barik, 2019). STW refers to untanned and tanned proteinaceous waste that requires adequate processing before being disposed of in an environmentally beneficial manner. Various approaches to reducing and recycling STW have been developed over time, resulting in the production of renewable energy sources such as biogas and biohydrogen, biofuels such as biodiesel and briquettes, construction materials, fertilizers, commercial products such as adsorbents, animal feeds, proteins, fats, and enzymes, and biodegradable materials for packaging and non-packaging purposes (Jothilingam et al., 2023). A diverse range of products has been developed from leather waste, including biodiesel, biogas, biopolymers, adsorbent materials, and agricultural applications among others (Rigueto et al., 2020).

According to global statistics, the total number of cowhide processed across various leather markets annually amounts to a staggering 300 million. However, this adversely impacts the environment, with nearly 300 million tonnes of tannery effluent being generated each year. Brazil, which is home to a large leather industry, alone consumes an amount of water equivalent to the daily consumption of 5.5 million individuals. In fact, on average, the country's tanneries utilize around 150 L of water every day to process leather (Streit et al, 2013).

The existing method of brick construction is very unsustainable since it consumes a huge quantity of natural resources, resulting in resource depletion and major environmental harm. However, there is a feasible alternative to this manufacturing method that uses industrial waste materials and is consistent with the Indian government's waste-to-wealth goal. This study employed tannery waste, fly ash, GGBS, and lime to make non-burning Sustainable Green Bricks (SGBs). As a binder material, a combination of lime, fly ash, and GGBS was used in the manufacturing of SGBs. Tannery sludge was added to the binder mix in various ratios, with the maximum percentage being 30%, and the resultant slurry was used to make mortar. The resultant mortar was then hardened and stabilized, and both SGBs with and without previous carbonation were water-cured (Jothilingam et al., 2023).

37.2 Characteristics and Challenges of Tannery Waste

37.2.1 Types of Tannery Waste

1. Solid Waste

The European Commission stated that the amount of solid waste generated in tanneries is dependent on several influencing factors such as the type of leather produced, the technology employed, and the availability of hides and skins. The types of solid waste generated in the tanning process can be classified into four categories, namely:

- tanned collagen,
- untanned collagen,
- non-proteinaceous waste, and
- non-collagenous protein waste (Basegio et al., 2002).

37.3 Liquid Waste

Liquid waste characteristics created in tanneries vary not only in kind but also with time. Once processed by soaking, liming, and deliming, the water produced by the beam house presents an alkaline environment, housing organic nitrogen, degraded organic matter, hair, sulfide, and high BOD, along with chemical oxygen demand (COD). Due to the presence of organic matter in the garbage, the process of microbial breakdown leads to a decrease in dissolved oxygen levels, consequently having a detrimental effect on aquatic animal life. This highlights the importance of proper waste management practices in order to mitigate the negative impact on our ecosystem (Mwinyihija et al., 2006).

37.4 Gaseous Waste

Tanneries release harmful pollutants such as dust, foul odors, and smoke into the environment. The main culprits of these odors in the tanning industry are nitrogen and sulfur. Animal hides begin to decompose immediately after removal from the animal's body and before proper curing. If hides are not cured in a timely manner, they may not exhibit a foul odor when initially salted, but the curing salt is removed during soaking, increasing the likelihood of protein putrefaction and bacterial growth (Patel et al., 2021).

37.4.1 Characteristics of Tannery Waste

1. Soaking, degreasing, unhairing and liming, deliming, softening, pickling, tanning, neutralization, retanning, coloring, and fatliquoring are all steps in the tanning process. These steps frequently need the application of numerous chemicals, resulting in effluent containing a plethora of pollutants. Furthermore, because of the presence of organic compounds and dispersed particles, the tannery effluent has a high alkaline and saline content.
2. Consequently, due to the presence of organic waste and suspended particles, the water has a repugnant smell and has an elevated oxygen consumption, measured by high BOD and COD levels. Additionally, it possesses a dark hue.
3. The quantity of water used during leather production significantly differs depending on the process, as different technologies are employed in the creation of various leather types. Additionally, the amount of water needed to produce a certain type of leather differs greatly due to the particular operational or processing techniques used at each stage (Zhao & Chen, 2019).
4. The provision and standard of water experience significant fluctuations due to the procedures implemented in various tanneries, with each procedure mostly remaining stable and requiring a specific duration to complete. The release of tannery wastewater often occurs sporadically, resulting in a wide range of quality variations in the effluent (Gutterres et al., 2015).
5. De Nicola et al. studied the toxicity of three forms of tanning wastewater in Marrakesh, Morocco: conventional tanning wastewater (TT), chromium-based tanning wastewater (CT), and vanadium-based tanning wastewater (VT). They carried out a series of bioassays to determine the toxicity of wastewater to various aquatic creatures, including sea urchins, Daphnia magna, and marine microalgae. According to the study, all three forms of tanning wastewater (TT, CT, and VT) are possibly dangerous (De Nicola et al., 2007).

37.4.2 Challenges Faced Due to Tannery Waste

The process of tanning animal hides and skin into leather involves the use of tanning agents, which can have negative impacts on the environment. The tanning industry is a major pollutant due to the high oxygen demand, discoloration, and toxic chemical constituents of the effluent discharge. The discharge can lead to soil and water pollution, as well as affect vegetation and terrestrial and atmospheric systems if not properly treated. Effluent from the tanning process is often extremely cloudy, colored, and odorous (Dargo & Ayalew, 2014).

Tanning plays a crucial role in the leather industry, with approximately 90% of tanneries worldwide relying on chromium salts to enhance the quality of leather by improving its elasticity, water resistance, and shrinkage temperature. However, there is a concerning issue regarding the use of chromium salts in tanning. Despite efforts to fix the chromium salts in the skins, a significant residual amount, approximately 30% of the initial quantity, remains in the spent tanning liquor. This residual amount of chromium, specifically in the form of Cr(VI), poses serious health and environmental risks. High concentrations of Cr(VI) have been found to have carcinogenic, mutagenic, and teratogenic effects on humans, as well as on various plants, animals, and aquatic organisms. Exposure to chromium in tanneries can lead to various adverse health effects, including dizziness, headaches, irritation of the eyes, skin, or lungs, allergic reactions, liver or kidney poisoning, neurological issues, and even oxygen deprivation-induced collapse. The discharge from tanneries is considered the most environmentally harmful among industrial waste streams. There are two main types of tannery effluents: vegetable tanning, utilized for heavy leather products like shoe soles, handbags, straps, and belts, which does not involve chromium, and chrome tanning, used for light leather preparation, containing chromium.

The chemicals and dust present in tanneries can enter our bodies through inhalation, absorption through the skin, and the food we consume via the food chain. Tannery effluent wastewater rapidly interacts with the surrounding environment. To minimize treatment costs, the sludge generated is often mixed with agricultural soil to enhance productivity. Additionally, a combination of physical, chemical, and biological treatment methods is employed to treat the wastewater, which is then used for irrigation purposes. However, irrigating plants with untreated effluents negatively impacts plant respiration, photosynthesis, mitotic activity, and overall growth and development. It also contributes to increased soil acidity, further exacerbating the environmental consequences (Tadesse et al., 2017).

37.4.3 Environmental Impact of Tannery Waste Disposal

Pollution from tannery firms contributes to the very bad ecological situation with which we are currently dealt with. The tannery firms are contaminating the environment day by day due to poor management practices, and the situation is worse as almost 95% of tannery industries are established in an uncontrolled manner around the entire world (Szpyrkowicz et al., 2005). Chromium salts are used in the majority of tanneries around the world for tanning in order to give leather better water resistance, flexibility, and high shrinkage temperatures. However, chromium salts are not completely fixed by hides, and the remaining nearly 70% join the spent tanning liquor (Cassano et al., 2007). According to (Patnaik, 2007), high levels of chromium lead to mutagenic, carcinogenic, and teratogenic effects on people, animals, numerous plants, and aquatic microbes. In a study by Lippmann (2000), this could result in symptoms like a headache, dizziness, irritated skin, eyes, and lungs, poisoning of the kidney, liver, or neurological system, as well as a collapse from a lack of oxygen. This Chromium pollution was especially noticeable in countries like India, Pakistan, South Africa, Latin America, Ethiopia, and Sudan, where many large tannery firms operate and all of them produce waste toxins used in the preparation tannery as well as some phenolics (Felsner & Kiruthu, 1996). More specific tannery effluents are studied by soil profiles, Water profile, vegetables and plant growth, atmospheric system, and human and animal health. Under the soil profiles, the agricultural soil in areas of Kanpur and Jajmau in India has been found to be heavily contaminated with heavy metals as a result of pollutants that are adversely affected by tanneries. Heavy metal deposition in soil is caused by continuous sludge irrigation, which includes cadmium, zinc, lead, chromium, manganese, and many other elements. Due to the soil's decreased ability to store heavy metals, this accumulation will eventually result in heavy metals being released into groundwater or soil solutions that plants can ingest. The presence of sodium carbonate, sodium bicarbonate, sodium chloride, and calcium chloride developed during the tanning process promotes the soil to become more alkaline, increasing the pH of the soil (Tadesse & Guya, 2017). According to Mwinyihija et al., 2006, waste released during the tanning process is made up of biodegradable organic matter, such as proteins and carbohydrates, which contributes to the decrease in the water body's dissolved oxygen content. Sulfide obtained during the tannery process has a negative impact on fish and other aquatic species.

Due to the high concentration of Chromium, sulfides, chlorides, high COD, and BOD in the effluents render them inappropriate for agricultural growth (Mishra & Bera, 1995), and decreased effluent dilution affects seed germination and seedling growth (Khan & Ghouri, 2011). Plants that are in the reproductive or vegetative phases should not be exposed to effluent concentrations higher than 80%. According to the Classification of Wastes 2009, particulate matter, tannery waste comprises polycyclic aromatic hydrocarbons (PAHs), ground-level ozone, carbon monoxide, heavy metals, benzene, sulfur dioxide, nitrogen dioxide, ammonia, and hydrogen sulfide as an outcome of the liming, deliming, unhearing, and bating processes. These pollutants mix with the air and cause air quality issues. Further exposure leads to poisoning of the liver and collapse of the kidney or nervous system due to limited availability of oxygen and in the long term leads to illness, such as ulcers, occupational asthma, genetic defects, bronchitis, and dermatitis, in humans as well as animal health (Tare et al., 2003). When tanneries' wastewater is used to irrigate crops, plants become stressed by salinity and develop phytotoxicity. It has an impact on several metabolic processes that, over time, cause plants to lose both their reproductive and vegetative growth. In addition to this, it impairs processes including photosynthesis, respiration, mitotic activity, and shorter germ sprouting, as well as increasing the amount of reactive oxygen species in the system (Camplin, 2001). By 2030, everyone should have access to basic sanitation systems, clean, safe drinking water, and other environmental sustainability goals set forth by the United Nations (Fito & Van Hulle, 2021).

The manufacturing of leather involves the use of hazardous chemicals. According to Vijayaraghavan and Murthy (Vijayaraghavan & Murthy, 1997), one tonne of raw hide yields 250 kg of finished leather, 48 m^3 of wastewater, 200 kg of sodium chloride, and 2–4 kg of organic salts. More than 600 kg of solid waste, including inorganic salts and organic waste, are produced during the leather-making process for every 1000 kg of raw skin (Boopathy et al., 2012). Due to the raw skin's albumin, globulin, blood, and tissues, which encourage bacterial contamination, sodium chloride is utilized in leather manufacturing to preserve the rawhide. NaCl has been added in an effort to stop the growth of germs on the rawhide (Annamalai et al., 2022).

37.4.4 Current Disposal Methods and Limitations

There are several approaches to industrial wastewater treatment that can be used to handle tannery effluents. These procedures use the fundamental ideas of unit operations and processes, which can include biological, chemical, or physical treatment technologies, as well as their mixtures. Biological procedures are generally selected because of sustainability and affordability factors, despite the availability of treatment technology. Biological processes can remove heavy metals from wastewater, mostly by adsorption and metal complexion with bacteria (Metcalf & Eddy, 2003). By utilizing microbes in an aerobic treatment chamber, it is possible to operate more sustainably, get rid of odors, turbidity, and color, and reduce chemical and biological oxygen demands (Pal & Kumar, 2020). On the other hand, because of the length of the procedure, ongoing observation, and optimization, it becomes less effective. Additionally, it experiences high-volume sludge accumulation, inadequate removal of persistent organic compounds found in wastewater, and the cost of the energy necessary to pump air into the system to maintain an acceptable level of oxygen for aerobic development (Valizadeh et al., 2022). However, as shown by the following examples, mixed microalgal culture can successfully remove heavy metals from wastewater: lead removal from industrial wastewater by Chlorella vulgaris and Chlamydomonas sp. (Golab & Smith, 1992) and chromium removal from synthetic wastewater using *Scenedesmus incrassatulus* (Pena-Castro et al., 2004).

Despite the fact that membrane fouling is one of the most prevalent concerns, these issues can be significantly handled by boosting the sweeping action by constructing crossflow membrane modules (Kumar & Pal, 2013). Despite this disadvantage, due to the wise application of microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO) regimes, membrane-based technologies can successfully lower the concentrations of harmful compounds such as chromium, sulfides, tannins, COD, and BOD (Kumar et al., 2022). For the separation of target pollutant removal or material recovery, hybridizing membrane technology with traditional methods may be more effective (Kumar et al., 2022). Adsorbents weren't too difficult to make; they mostly involved agent leaching, pyrolysis, drying, milling, and sieving, but the problem of how to guarantee consistent adsorption ability hasn't been solved. In addition to these inorganic substances, biosorbents formed from biomass have garnered a lot of interest. Numerous studies have documented the conversion of barks, fruit peels, reeds, charcoal, etc. into bio-sorbents (Hashem et al., 2019; Ugya et al., 2019; Sumathi et al., 2009; Namasivyam et al., 2004; Abul et al., 2020). Additional efforts have been made to introduce various microorganisms, including bacteria, fungi, and others, for the removal of contaminants in TWW, and these microbes themselves with their secretions showed good adsorption characteristics in numerous research (Tan et al., 2003; Aravindhan et al., 2012; Natarajan et al., 2018). A viable solution for TWW treatment has also been suggested: using microalgae for wastewater treatment. Recent research has shown that microalgae are capable of adsorbing harmful metals and other pollutants from diluted tannery effluent (Zhao et al., 2022).

Due to its exceptional ability to remove persistent pollutants under the tougher discharge criteria for waste effluents, advanced oxidation processes (AOPs) have become a research hotspot in recent years. Essentially, this strategy uses a number of approaches to generate significantly stronger oxidant species such as O_3, peroxy radical, hydroxyl radical, sulfate radical, and so on to target refractory organic pollutants in wastewater so that the effluents after treatment can meet the required quality. Many persistent pollutants in the TWW, such as tanning chemicals, polycyclic compounds, and metal complexes, are difficult to totally break down in the absence of AOPs (Korpe & Rao, 2022). The methods which were discussed above have their own limitations in biological treatment it is time-consuming, and inhibition by high salinity, massive sludge, and unstable effluent quality. Whereas membrane filtration also has some limitations such as serious membrane fouling, massive sludge, and more capital investment in the power supply when treatment throughput is large. Nevertheless, the adsorption of massive sludge formation, and pollutant transfer, are not suitable for large treatment throughput (Zhao et al., 2022). This advanced oxidation process has some limitations such as requiring the addition of chemical agents, optimal reaction conditions needing to be regulated, and the toxicity of reaction by-products needs further inspection.

37.5 Treatment and Processing Techniques for Tannery Waste

The treatment of tannery waste poses unique challenges compared to other types of industrial waste, and there is no singular solution that can completely address the issue. However, efforts have been made to utilize the non-tanned waste generated in tanneries for various purposes. This waste is often employed as a raw material in the production of glue, gelatin, protein sheaths, and fertilizers. Additionally, it can serve as a substrate for the generation of biogas through anaerobic digestion processes. In recent years, researchers have developed several treatment strategies to tackle the harmful effluents generated by tanneries. One such approach involves treating raw vegetable tannery effluent with poly aluminum chloride (PACL), both as a standalone method and in combination with a coagulant, using the coagulation-flocculation technique (Borchate et al., 2012).

37.5.1 Removal of Chromium

Chromium (III) is the preferred tanning agent in the leather industry due to its excellent processability and ability to produce high-quality end products. In the tanning process, chromium salts are applied to the hide, resulting in the formation of crosslinks between collagen fibers. This crosslinking enhances the durability, flexibility, and resistance to the decomposition of the hide. However, the effluent from the tanning process, known as tannery waste liquor, contains varying levels of chromium (III), typically ranging from 2000 to 5000 mg/L. It is important to note that this effluent cannot be discharged into the environment without proper treatment. In addition, the reuse of chromium extracted from tannery waste presents an opportunity to decrease the energy consumption and costs associated with chromium ore production and processing. Therefore, it is crucial to develop environmentally friendly and sustainable technologies for the collection and recovery of residual chromium (III) (Selvaraj et al., 2018).

37.5.1.1 Membrane Electroflotation

The combined technique of electrocoagulation and electroflotation (EC-EF) has been examined as a potential solution for the removal of heavy metals from polluted water. This method utilizes a soluble iron or aluminum anode to initiate the coagulation of dissolved heavy metals through the EC process. Following this, hydrogen/oxygen bubbles generated during the EF process cause the coagulated heavy metals to rise to the surface. Various anodes, including titanium, iron, and graphite, have been employed in research to eliminate chromium from tannery wastewater. However, it is important to recognize that the EC-EF technique generates sludge containing iron/aluminum, which cannot be directly reused and necessitates further treatment.

In a specific study, a dual-chamber membrane electrochemical reactor effectively recovered chromium from high chloride-laden tannery waste liquor supplied by CSIR-CLRI, without oxidizing it into the hazardous Cr(VI) form. Researchers found that in a single compartment, the existence of active chlorine species resulted in the oxidation of chromium into its dangerous Cr(VI) state. Additionally, the scientists successfully produced a chrome tanning agent using the recovered chromium hydroxide and evaluated its performance in comparison to commercially obtainable basic chrome sulfate (Selvaraj et al., 2018; Suthanthararajan et al., 2004).

37.5.1.2 Ceramic Microfiltration and Reverse Osmosis

In order to address the limitations associated with conventional treatment methods, researchers have proposed various new and cleaner technologies for the treatment of tannery wastewater. Among these, membrane processes have gained significant attention. Recent studies have focused on the application of nanofiltration and reverse osmosis for treating tannery wastewater collected from beam house units. The treatment process typically involves biological pretreatment, followed by a physicochemical treatment using a polymeric coagulant, and finally, the use of membranes in the reverse osmosis (RO) step. Ceramic membranes have proven to be effective in treating both industrial and domestic wastewater. The sludge generated from microfiltration (MF) is subsequently treated using RO as the second step (Bhattacharya et al., 2013).

To ensure the efficacy of the RO process, pretreatment is crucial as fouling can occur in the RO membrane due to the presence of hard scales and soft amorphous complexes in the wastewater. Research conducted by Bhattacharya et al. demonstrated that the direct microfiltration process can achieve a reduction of 91% in chemical oxygen demand (COD) and biochemical oxygen demand (BOD), a 62% reduction in total organic carbon (TOC), and complete removal of sulfide. Additionally, the turbidity of the treated effluent can be reduced to below 1 NTU. Interestingly, the leather produced using the treated water exhibited better quality in terms of physical properties compared to the control samples. The treated effluent also showed enhanced dye uptake in the leather, while the tensile strength of the leather was approximately 19% higher and the elongation was approximately 38% higher compared to leather tanned using fresh water (Bhattacharya et al., 2013; De Gisi et al., 2009; Selvaraj et al., 2018; Suthanthararajan et al., 2004).

37.5.1.3 Biological Treatment

Biological treatment methods offer several key advantages. Firstly, they provide cost savings in terms of both capital investment and operational expenses compared to traditional chemical oxidation techniques. Secondly, unlike methods such as air stripping or activated carbon, the biological treatment ensures the complete mineralization of organic compounds rather than just phase separation.

Additional Benefits of Biological Treatment Include:

(1) Efficient removal of a wide range of organic compounds through processes like microbial degradation and biomass-based adsorption.
(2) Oxidation of diverse organic compounds.
(3) Reduced inorganic compounds such as sulfides and ammonia are effectively removed.
(4) Total nitrogen removal is achieved through denitrification.
(5) Operational adaptability to deal with variable flow rates and effluent properties.
(6) Reduced water toxicity, which contributes to enhanced environmental health (Jahan et al., 2014).

Coagulation and Flocculation

Coagulation-flocculation (CF) has been researched as a technique for treating tannery effluent in the literature. Inorganic coagulants such as aluminum sulfate, ferric chloride, and ferrous sulfate have been used to decrease organic load (COD) and suspended particles (SS) in wastewater and remove hazardous chemicals. Heavy metals such as chromium must be removed prior to biological treatment. The authors reported effective entire chromium removal with alum and full chromium elimination with ferric chloride. Furthermore, $FeSO_4$, $FeCl_3$, and alum have been used to remove 40–70% of COD and more than 99% of total chromium from leather tanning effluent.

Bioleaching

Bioleaching has shown to be a viable and cost-effective approach for removing chromium (Cr) from tannery sludge. According to Ma et al., acidification of tannery sludge causes Cr solubilization by both direct and indirect processes, which are aided by *Acidithiobacillus* species, namely *Acidithiobacillus ferrooxidans* and *Acidithiobacillus thiooxidans*. The chromium recovered from the bioleaching method has the potential to be reused in the tanning process. However, the presence of high iron content in the bioleachate might affect chromium absorption by wet blue. Current tannery practices extracting chromium from bioleachate by alkali precipitation. However, because the addition of alkali precipitates both iron and chromium at the same time, the resultant chromium sludge is non-recyclable. As a result, it is critical to investigate the potential of recycling iron and chromium in the tanning process rather than extracting them from bioleachate. At a pH of 2.81, the solution may be successfully precipitated, allowing for the potential separation of Cr and Fe by adding alkali. However, immediately changing the pH with hydroxide does not separate chromium and iron effectively (Ma et al., 2017).

37.5.2 Sodium Sulfide Recovery and Removal

In the leather industry, sodium sulfide is widely known for its versatility and frequent use as a depilatory chemical. The technique, which utilizes sodium sulfide and Ca_2, accounts for 84% of the biological oxygen demand, 75% of the chemical oxygen demand, and 92% of suspended particles in pre-tanning wastewater. These salts play a significant role in the increased levels of nitrogen found in wastewater. To make the leather production process more environmentally friendly, it is crucial to find and implement a less harmful alternative to this method (Andrioli et al., 2015).

37.5.2.1 Enzymatic Unhairing

Numerous innovative approaches have been explored, including employing proteolytic enzymes in the unhairing process. Although enzymes are prevalent in various industries, their utilization in the leather sector remains rare. Enzymatic unhairing is a distinct example of enzyme implementation in the beam house, where proteolytic enzymes specifically target hair roots and the epidermis. This method significantly reduces the number of chemicals involved compared to traditional unhairing techniques. In order to determine the required duration for enzyme-based unhairing, the researchers carried out a series of kinetic experiments. Their findings revealed that within 6 h, it is possible to effectively remove hair from hides without inflicting damage to the grain and ensuring adequate elimination of inter-fibrillary proteins. The complete enzyme-driven unhairing process takes 24 h for cow hides, 18 h for goat skins, and as long as 12 h for pig skins (Murugappan et al., 2016).

37.5.2.2 Aqueous Ionic Liquid Solution

Various agents have been examined for their capacity to accomplish the essential reduction of sulfide bonds. It is important to consider that enzymes may be susceptible to storage environments and the temperatures they are utilized in, potentially leading to inconsistent results. Although this depilation technique was effective, it caused undesired damage to the final product. In rare instances, alkaline calcium peroxide has been employed to remove hair. Nonetheless, producing ozone requires specialized equipment, increasing both the initial investment and ongoing operational costs of this process. Another study explored a broader range of aprotic cationic liquids, such as salts comprising thioglycolate anion and dihydrogen phosphate anion (Vijayaraghavan et al., 2015).

37.6 Fabrication of Construction Materials from Tannery Waste

37.6.1 Tannery Sludge in Brick Manufacturing:

Dealing with chromium-laden tannery waste in Bangladesh presents an ecological dilemma. A possible remedy involves stabilizing the sludge by integrating it into clay brick materials. Nevertheless, to ensure sustainability and environmental safety, it is vital to confirm that the sludge incorporation does not undermine the bricks' engineering qualities, that the procedure remains energy-efficient compared to other options, and that employing such bricks does not yield long-lasting adverse consequences.

The compressive strength of bricks containing sludge varied from 10.98 MPa to 29.61 MPa, while their water absorption fluctuated between 7.2% and an amount that generally met both Bangladesh norms and ASTM standards for construction materials. Notably, the sludge-enhanced bricks produced in brick kilns were of lesser quality compared to those made in the laboratory. This difference in quality can be attributed to the less regulated environment within brick kilns, which impacts factors such as compaction and moisture content.

Furthermore, studies on the leaching behaviour of heavy metals from sludge-amended bricks showed insignificant levels of leaching, falling well below the regulatory limits set by Dutch regulations and the USEPA. This suggests that the potential environmental impact of using these bricks is minimal. Overall, stabilizing tannery sludge in clay bricks holds promise as a means of addressing the environmental burden posed by the sludge, provided that proper considerations are made to maintain the desired brick properties and ensure long-term environmental safety.

As the TS content increased, water absorption rose and compressive strength decreased, mirroring previous studies on sludge-incorporated construction materials. Despite this, bricks with TS additives often met both BDS and ASTM standards for building bricks. Incorporating 10% TS by weight could be an ideal formula for creating TS-enhanced bricks without compromising their technical properties. Although the 10% TS bricks manufactured in commercial kilns were of lower quality compared to those produced in the lab, they still met the necessary strength criteria for construction materials. Bricks with added TS exhibit desirable features such as reduced shrinkage, weight, and bulk density while eliminating efflorescence, making them suitable for various applications. Furthermore, incorporating 10–40% TS content in bricks has the potential to significantly lower firing energy by 15–47%, leading to cost savings and promoting the long-term use of these bricks (Juel et al., 2017).

37.6.2 Tannery Waste in Preparation of Clay Roof Tiles

A study was carried out to explore the replacement of traditional raw materials in roof tile manufacturing with dried tannery waste (TW) powder. Various weight percentages of TW powder, from 0 to 35%, were incorporated into a raw mix composed of three kinds of clays, feldspar, and grog. To prepare the samples, 15.6% of the raw mix was combined with an adequate amount of water to attain the required plasticity, and then molded into rectangular steel molds. The dry samples were tested for linear shrinkage and mechanical strength. The firing process was executed in a muffle furnace following a specific heating schedule with temperatures from 1000 °C to 1150 °C. Sintering properties, efflorescence, frost resistance, and mechanical strength were evaluated for the fired samples to ascertain their quality and performance. The incorporation of TW powder into standard roof tile mixture aimed to address environmental concerns associated with landfill waste while also reducing production costs by repurposing valuable waste material. Conventional mixtures were substituted with solid waste in concentrations up to 35% (Amin et al., 2022).

37.6.3 Tannery Waste Used as Fine Aggregates

Chen et al., experiment study explored the possibility of replacing fine aggregates and cement with tannery sludge in concrete production while utilizing only recycled coarse aggregates. The research showed that, depending on the treatment used, sludge could function as both a cementitious material and a weight-bearing aggregate. It was determined that the ideal replacement rate for cement was 10% and 4% for fine aggregates. As the sludge replacement rate increased, the concrete's compressive strength decreased. A notable increase in 28-day compressive strength by 13.9% was observed when 4% of fine aggregate was replaced with sludge, resulting in a strength of 18.9 MPa, which met general sidewalk design requirements. However, further increases in substitution rates led to declines in both workability and compressive strength. NMR studies indicated a correlation between the 28-day concrete's porosity and compressive strength trends, with micropores dominating the sludge-mixed concrete and fewer small pores present. Additionally, elevated sludge replacement rates caused a significant reduction in healthy pores and an increase in sub-healthy pores, affecting the concrete's durability to a certain degree. The water absorption rate was directly influenced by the sludge replacement rate, showing a positive relationship with the sludge content in the concrete mix (Chen et al., 2022).

37.6.4 Tannery Waste to Prepare Thermal Insulation Panels

In this research, thermal insulation panels were created by merging buffing dust, a byproduct from tannery waste, with polystyrene. The panels comprised a weight percentage ratio of 20% buffing dust, 77% polystyrene, and 3% blowing agent. Samples were prepared using a co-twin extruder at 210 °C. The resulting composite panels displayed enhanced thermal insulation capabilities compared to regular polystyrene boards. Furthermore, the panels retained their mechanical properties, showcasing impressive thermal conductivity, density, compression strength, and water absorption. Thermogravimetric analysis showed the panels' thermal stability ranging from 200 °C to 412 °C. Scanning electron microscopy (SEM) revealed the presence of voids in the composite upon integrating the buffing dust, causing reduced homogeneity. Energy-dispersive X-ray (EDX) examination verified that the composite contained 62% carbon and 0.2% chromium. These results suggest that the developed composite panels are a potential option for use as thermal insulation boards in the construction sector, promoting waste recycling from leather production and decreasing environmental pollution. Thermogravimetric analysis (TGA) confirmed the outstanding thermal stability of the composite panels. The inclusion of phenyl groups in the composite materials lessened hydrogen bonding, and a drop in density was associated with a reduction in homogeneity. This study emphasizes the possibility of repurposing tanneries' buffing dust waste by incorporating it into polystyrene, improving the thermal insulation attributes of the composite panels while maintaining other mechanical properties. As a result, this innovative composite material offers an attractive alternative for thermal insulation uses within the building industry (Ulfat et al., 2021).

37.7 Technological Advancements and Innovations

37.7.1 Research and Development in Tannery

Wastewater treatment has been seen as useful for controlling water sources. Treatment of tannery wastewater effluent is a challenging issue that requires a thorough study of various treatment approaches. Various techniques were involved in this effluent treatment obtained from the tannery coagulation/flocculation, advanced oxidation processes (AOPs), biological treatment, membrane separation processes (MSPs), adsorption, and hybrid technologies are a few examples of treatment techniques (Bhardwaj et al., 2023). Even with continual improvements, it is still difficult and expensive to completely detoxify stubborn organic and inorganic contaminants in TWE using just one approach (Jallouli et al., 2022; Shahbazi & Pedram, 2021). According to studies, integrating various treatment modalities can result in a more successful and economical strategy. By carefully weighing the benefits and drawbacks of each technique, an appropriate set of methods can be combined to produce cost-effective performance and many benefits. According to Grandclément et al. (2017), this is a growingly common tendency among researchers studying tannery effluent treatment who have been experimenting with various ways to get better outcomes. Most COD was removed when RO, NF, gravity settling, and coagulation/flocculation were used in hybrid treatments. Following the simultaneous application of NF, which removed 91% of COD, and RO, which removed 99% of COD, coagulation and flocculation eliminated 64% of COD. In other hybrid techniques, adsorption was used as a pre-treatment following coagulation or flocculation (Mella et al., 2018, 2019; Puchana-Rosero et al., 2018). In order to increase the tannery wastewater effluent (TWE) biodegradability during biological treatment or to remove any remaining refractory pollutants after biological procedures, several AOPs can be utilized (Caliari et al., 2022). These integrated/combined/hybrid techniques have pros such as high pollutant removal efficiency, cost-effectiveness, and the ability to treat a wide range of pollutants and a few cons such as the complexity of the treatment process may lead to operational difficulties and maintenance issues. Although integrated technologies have many advantages, they must be implemented and operated with these possible disadvantages carefully taken into consideration (Bhardwaj et al., 2023).

The tannery is one of the industries to which nanotechnologies have recently been applied. In particular, nanomaterials were and are being researched and produced to treat emissions, particularly wastewater, and to limit and decrease the effects of the processes. The majority of nanomaterial activities are currently conducted on a small scale in laboratories. It is advantageous that their applicability is shown to be applicable for both process sustainability and final leather quality in order to quickly transition these activities to an industrial scale. Numerous nanomaterials have been explored and created for the treatment of wastewater, particularly to remove chromium(III). In a nutshell, there are still a lot of efforts to be made and a lot of options open for the use of nanomaterials in the tannery. The manufacturing of nanoparticles effective in some tannery activities will also need to show that it is sustainable for worker health and environmental protection (Chiampo et al., 2023). As we know, the continuous discharge of chromium from the tannery industry causes several environmental pollutants in various water bodies, it is essential to create a technique that is both economical and safe for the environment. According to Jannat et al. (2023), the water hyacinth (Eichhornia Crassipes) roots were used to successfully extract chromium from tannery effluents. Using common spectrophotometric methods including UV-Vis and atomic absorption spectroscopy (AAS), it was investigated how much chromium was present in wastewater bodies before and after the biosorption procedures. By adjusting the biosorbent doses, temperature, and initial chromium ion concentrations, the metal removal capability of water hyacinth roots was ascertained. Over 95% of the chromium could be removed from diluted tannery wastewater to the greatest extent, and water hyacinth at various dosages could also absorb 72% of the chromium directly from raw tannery effluents.

37.8 Regulatory Framework and Challenges

37.8.1 Environmental Regulations and Compliance

The general public, as well as tannery owners and staff, has to be made aware of the harm that untreated tannery effluent discharge and careless disposal of tannery solid wastes can do to people's health and the environment. It's essential to comprehend the direct relationship between solid and liquid wastes, air, land, and water. Surface water and groundwater sources will afterward get contaminated by waste that has been dumped in the air or on land. It is important to underline the dangers of drawing water for public supply from contaminated sources, the resistant character of contaminants like chromium, as well as their detrimental impact on health. Such contaminants are challenging to eliminate using traditional wastewater treatment techniques and may still be present in drinking water (Mohammed, 2017).

Enforcement of environmental laws governing effluent discharge limitations is necessary to ensure compliance by tanneries that dispose of solid waste and release untreated effluents into waterways. Authorities charged with preserving the environment and defending public health must make sure tanneries have effective effluent treatment facilities (ETFs) and that these ETFs are frequently run and properly maintained. Wherever necessary, businesses should be pushed to adopt less expensive but environmentally friendly waste management techniques. This will help in achieving compliance (Mohammed, 2017).

If there are defaulters, it may be necessary to assess the necessity for a penalty or censure. This may need the application of the "polluter pays" principle, which holds the responsible creators accountable. When necessary, actions against rule breakers may include hefty monetary fines, interim or even permanent bans, and other sanctions. This will contribute to the preservation of both the environment and public health (Mohammed, 2017).

37.8.2 Health and Safety Consideration

Due to the possible risks associated with tannery waste, health and safety issues are of the highest importance. Here are some important health and safety factors to take into account such as personal protective equipment (PPE): Necessary PPE shall be provided for all staff. The staff shall have to wear PPE as may be required in different areas of the industrial plant. Examples for PPE (not complete, may differ in different sections and tanneries) such as earplugs, protective masks, shoes, and aprons (i.e., mainly in soaking/liming/fleshing, including handling of fleshings); Provide clear labels on the requirements of PPE visibly on the machines, operating rooms and other areas (e.g., buffing room, milling room, color kitchen); Electrical control boards must have closed doors, be tidy and dry, and if necessary, have fans to help cool the machinery; Drainages and floor pits must be safely sealed off without any gaps; In the locations where chemicals are stored and handled, safety showers and eye showers must be available; Emergency exits and emergency meeting points shall be clearly marked and accessible; All staff members must receive regular training in safety, emergency situations, and first aid at least four times each year (Sahasranaman, 2000). There is relatively little information on how dangerous substances should be handled and stored. Small-scale tanning facilities measure and combine chemicals by hand. At the same time, steps that could boost productivity or quality, such as optimal lighting, office design, alternative material handling methods, and increased housekeeping, receive little attention. Due to a lack of knowledge and understanding about the existing health hazards and safety risks at work, tannery workers are not adequately protected, and they are not well prepared for fire or medical emergencies (Kral, 2014). Maintaining the above few steps could help the person working in the tannery sector in good. The dangers to workers, communities, and the environment can be successfully reduced by prioritizing health and safety considerations in tannery waste management. For the safe handling and processing of tannery waste, sufficient safety measures, adequate training, and regulatory compliance are required (Fig. 37.1 and Table 37.1).

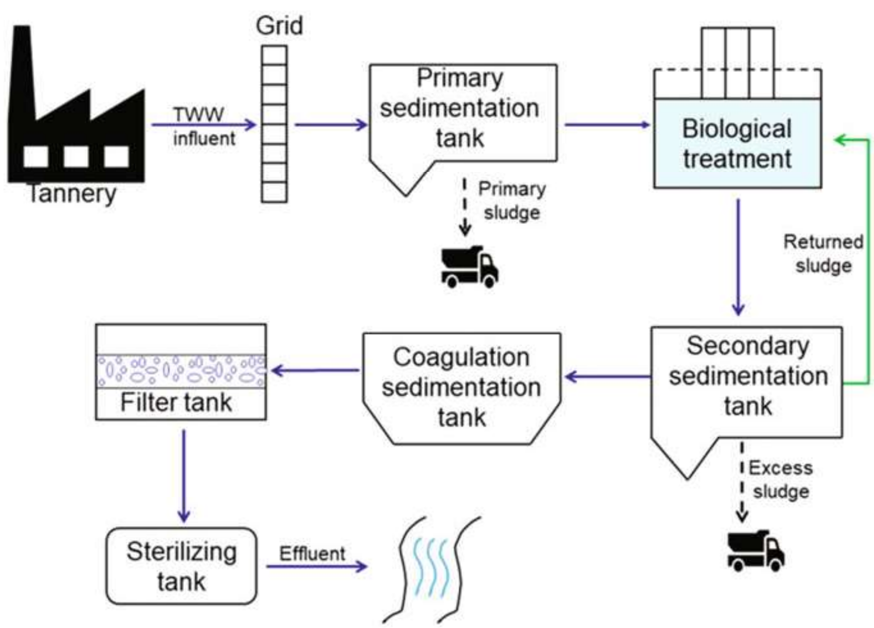

Fig. 37.1 Tannery wastewater treatment (Zhao et al., 2022)

Table 37.1 Types of pollutants released during the tannery process in the leather industry

Name of the process	Air pollutants	Solid pollutants	Water pollutants	References
Socking	–	–	Salt, organic nitrogen, COD, BOD, DS, and SS	Tadesse et al. (2017)
Liming/ unhairing	Hydrogen sulfide	Hair, lime, organic sludge	–	
Lime fleshing	–	Fat containing lime	Alkalinity, sulphides, BOD, COD, TDS, and SS	
Liming splitting	–	Lime split and limed organic matter		
Bating/ deliming	Ammonia (NH_3)	–	BOD, COD, TDS, ammonia	
Degreasing	–	–		
Tanning	–	–	Vegetable tans, syntans, and acidity of added chemicals	
Chrome splitting	–	Cr-containing organic matter	–	
Shaving	–	Chrome-containing organic matter	–	
Retanning	–	–	Fats, dyes, vegetable tans, syntans, BOD, COD, dissolved and suspended solids	
Drying	–	–	–	
Bating/ trimming	–	Formaldehyde and chrome trimming	–	
Finishing	Formaldehyde and solvents	–	–	

37.9 Sustainability and Circular Economy Perspectives

37.9.1 Social and Environmental Benefits

A significant amount of waste is produced during the manufacturing of leather, and this waste can serve as raw materials for many industries (Fig. 37.2). According to published statistics (Sathish et al., 2019), tannery wastes are processed to create re-tanning agents. These wastes are a source of chromium, which is thereafter properly treated and used in the production of leather. Utilizing tannery waste to create fertilizer is a novel development in zero-waste manufacturing. A nitrogen-rich semi-product that can be one of the ingredients in NPK fertilizers can be produced by the acid or alkaline hydrolysis of leather waste (Majee et al., 2019). Due to legal restrictions, the procedure allows for the removal of chromium from fertilizer formulations (Scopel et al., 2016). The amount of waste that would otherwise wind up in landfills or open dumping sites is decreased when tannery waste is incorporated into construction materials. This lessens the strain on the infrastructure for waste management and lowers the threats to the environment by means of lowering waste and saving the ecosystem. Engaging local communities in tannery waste utilization projects promotes empowerment. By fostering a sense of ownership and shared responsibility for environmental care, it promotes community involvement in waste management decisions. Sludge, hair, and leftover pieces of flesh are among the trash that tanneries produce in large quantities. The amount of garbage that needs to be disposed of is decreased by using these waste products in the manufacture of construction materials. This encourages garbage management and recycling, which eases the load on landfills and waste treatment facilities.

According to a circular economy chain, hydrolysis enables the manufacture of two value-added products, a fertilizer semi-product, and a chromium concentrate. This kind of trash can be recycled in place of inorganic fertilizers. This strategy

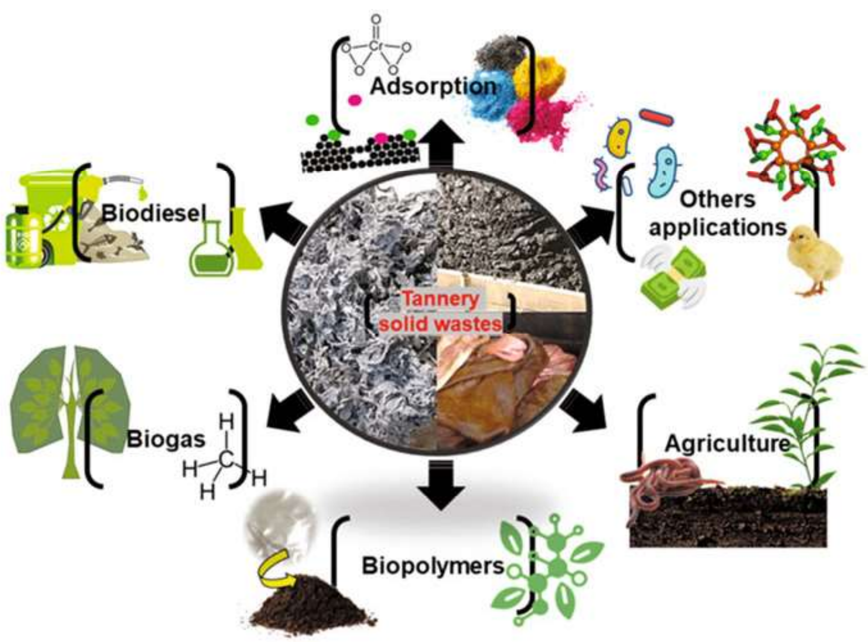

Fig. 37.2 Alternate uses of tannery waste (Rigueto et al., 2020)

is a more eco-friendly one (Silva et al., 2010). Fulfilling the tenets of the circular economy plan and green production has numerous advantages. However, there are a number of procedures that must be taken before these solutions can be implemented, including an economic analysis and a technical feasibility assessment (Chojnacka et al., 2021).

37.10 Conclusion

The effective utilization of tannery waste for the fabrication of construction materials holds great potential in addressing both environmental and economic challenges. By harnessing the value of this waste stream, we can reduce its negative impact on the environment and promote sustainable practices in the tanning industry. The benefits of utilizing tannery waste in construction materials are numerous, including waste reduction, energy efficiency, and improved material properties. By incorporating tannery waste as aggregates, fillers, binders, or even as a source of renewable energy, we can minimize the reliance on virgin materials, reduce greenhouse gas emissions, and conserve natural resources. Additionally, the utilization of tannery waste in construction materials contributes to the circular economy by closing the loop on waste generation, transforming it into valuable resources.

However, challenges such as quality control, environmental considerations, and technological advancements need to be addressed for widespread implementation. Establishing robust quality assurance protocols and standards is crucial to ensure consistent material properties and performance. Proper handling, treatment, and monitoring of toxic substances in tannery waste, such as chromium, are vital to safeguard the environment and human health. Furthermore, ongoing research and development efforts are essential to enhance processing techniques and develop innovative technologies that maximize the utilization of tannery waste in construction materials. To fully unlock the potential of tannery waste, collaboration among stakeholders is paramount. Academia, industry, and government institutions should work together to exchange knowledge, share best practices, and create a supportive regulatory framework. This collaborative approach will drive technological advancements, foster innovation, and facilitate the adoption of sustainable practices across the tanning and construction sectors.

In conclusion, the effective utilization of tannery waste for the fabrication of construction materials presents a promising pathway toward a more sustainable and circular economy. By transforming waste into valuable resources, we can mitigate environmental pollution, reduce resource depletion, and promote the development of high-performance and eco-friendly construction materials. Embracing this approach will not only benefit the tanning industry but also contribute to the overall sustainability of the construction sector, fostering a greener and more resilient built environment for future generations.

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Chapter 67
Newspaper Waste Management and Various Technologies and Approaches for Converting Newspaper Waste into Valuable Products

Chittepu Obula Reddy and V. Shreya Sharma

Abstract Newspapers are an integral part of modern society, providing a vital source of information and entertainment to millions of people around the world. However, as technology has advanced, the use of newspapers has declined, leading to an increase in the amount of paper waste generated each year. The traditional approach to managing paper waste has been to recycle it into new paper products, such as newspapers, books, and packaging materials. While recycling is an essential component of a circular economy, it is not the only solution. Newspaper waste is not only an environmental issue but also a missed opportunity for creating value from abundant and readily available resources. In recent years, there has been a growing interest in finding innovative ways to convert newspaper waste into value-added products. Methods for managing this newspaper waste and converting them to value-added products such as biodegradable packaging, building materials, insulation, biogas, biopesticides, nanoparticles, enzymes, and many more such products are described in this book chapter. This book chapter also provides an overview of the current state of newspaper waste management and explores the potential of various technologies and approaches for converting newspaper waste into valuable products.

Keywords Newspaper waste · Cellulose insulation · Biodegradable packaging · Biogas · Biopesticides · Enzymes

C. O. Reddy · V. S. Sharma (✉)
Department of Biotechnology, Chaitanya Bharathi Institute of Technology, Hyderabad 500075, India
e-mail: sharmav080102@gmail.com

C. O. Reddy
e-mail: cobulreddy_biotech@cbit.ac.in

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67.1 Introduction

Paper waste is a major issue in the modern world, with an estimated 400 million tons of paper and cardboard generated annually. This waste paper can be used to make new goods, lower greenhouse gas emissions, and conserve energy. Recycling involves gathering, sorting, and processing waste paper to produce new paper goods. There are several ways to use waste paper, depending on the kind of paper generated, the calibre of the waste paper, and the purpose for which the recycled material will be used as shown in Fig. 67.1. Using waste paper is essential since it not only lowers the quantity of trash dumped in landfills but also lowers the need for virgin pulp and lessens the environmental effect (Kopinski & Kwiatkowska-Marks, 2012).

The most important details of the phrases waste paper, paper, and energy are that a ton of recycled paper may save 17 trees, 7,000 gallons of water, 3 cubic yards of landfill space, and 4,000-kilowatt hours of electricity. Burning waste paper produces heat and electricity, making it a useful and sustainable source of energy. Biogas, which may be used as a fuel for heating or transportation, can also be produced from waste paper. Another creative technique to exploit this important resource is to use waste paper in agriculture. When paper is composted, it breaks down into organic matter, which can be used as a soil amendment to improve soil structure and nutrient content. The use of waste paper has the potential to significantly affect the environment, but recycling newspaper can cut greenhouse gas emissions by up to 74% while saving up to 60% of the energy needed to make paper from virgin pulp (Bilal et al., 2017; Byadgi & Kalburgi, 2016; Kumar et al., 2020a, 2020b; Xia et al., 2016).

Science publications have shown proof of the advantages of using waste paper. For instance, University of Illinois research indicated that recycling paper can save up to 64% more energy than creating new paper from fresh pulp. One ton of recycled paper can prevent up to 900 kg of CO_2 emissions, according to different research by the European Commission. In addition, research that was published in the Journal of Cleaner Production looked at how different waste paper utilisation techniques

Fig. 67.1 Different value-added products from Newspaper waste

affected the environment and discovered that recycling had the most potential to do so when compared to other use methods (Dahlbo et al., 2007; Okada et al., 2003).

In conclusion, newspaper is an important resource that ought to be used rather than disposed of in landfills or burned in incinerators. Using newspaper waste in agriculture, energy production, recycling, and other processes can conserve energy, lower greenhouse gas emissions, and have a positive environmental impact. Using newspaper waste has been shown to have advantages, and it is essential that people and organisations work to minimise waste paper and boost use in order to reach a more sustainable future (Kumar et al., 2020a, 2020b).

67.2 Traditional Approaches

Waste paper is currently being utilised through various traditional approaches which are based on the principles of sustainability and resource conservation. Recycling involves collecting, sorting, and processing newspaper to make new paper products. Composting involves breaking down organic material, including waste paper, to create a nutrient-rich soil mixture. Additionally, newspaper is traditionally used as a source of fuel, where it is burned to generate heat and electricity. These traditional approaches are still relevant today and aim to minimise the environmental impact while also extracting its value (Rehmani et al., 2022; Shang et al., 2021).

However, they are more rudimentary than modern recycling efforts. Traditional approaches to waste paper utilisation include recycling, composting, and fuel production. Newspaper has also been used for a variety of crafts and artistic pursuits, such as origami, papier mache, and packaging materials. However, these approaches have several disadvantages, such as their limited scope and focus on a narrow range of waste paper sources. Additionally, traditional recycling programs often only collect specific types of paper, such as newspapers or cardboard, while other types of paper, such as glossy magazines or laminated paper, are not recycled. These disadvantages can limit the effectiveness of traditional waste management practices and undermine efforts to promote sustainability and resource conservation (Byström & Lönnstedt, 1995; Virtanen & Nilsson, 2013).

Traditional waste paper utilisation approaches are limited and can lead to inefficiencies. They often rely on manual labor to collect, sort, and process newspaper, which can be time-consuming and costly. Additionally, traditional approaches rely on fossil fuels, such as incineration, which can contribute to greenhouse gas emissions and can exacerbate climate change. Additionally, traditional approaches lack innovation and technology, such as single-stream recycling and automated sorting, which have significantly improved the efficiency and effectiveness of waste paper recycling. These disadvantages can prevent the full potential of waste paper utilisation from being realised and lead to resource depletion and energy insecurity (Orue et al., 2017; Su et al., 2017).

Newer technologies have made it easier for individuals and businesses to recycle waste paper and have increased the overall recycling rates in many communities.

Traditional waste paper utilisation approaches can be limited by the lack of infrastructure and funding, as well as social and cultural barriers. These barriers can be difficult to overcome and can prevent the adoption of traditional waste management practices. Additionally, traditional approaches may not take into account the needs and perspectives of diverse communities, particularly those in developing countries, which may have different cultural values and waste management practices (Joshi et al., 2017; Orue et al., 2017; Virtanen & Nilsson, 2013).

In conclusion, while traditional approaches to waste paper utilisation have many advantages, they also come with several significant disadvantages as shown in Table 67.1, highlighting the differences between traditional and innovative methods. These disadvantages can limit the effectiveness of traditional waste management practices and can prevent the full potential of waste paper utilisation from being realised. To address these limitations, it is important to continue to innovate and invest in newer, more innovative waste management practices that can overcome these challenges and promote sustainability and resource conservation (Joshi et al., 2017; Su et al., 2017).

Table 67.1 Comparison between traditional and innovative methods for newspaper waste utilization

Traditional methods	Innovative methods	References
Traditional approaches often involve simple recycling processes	Involve a more advanced technologies such as chemical treatment, or bioreactors	Dahlbo et al. (2007), Rodriguez et al. (2017), Gu et al. (2017)
Tend to focus on reducing the environmental impact of newspaper waste	Prioritises the extraction of valuable materials from the waste stream, such as cellulose fibers or biofuels	
Less investment is required and hence cost-effective in the short term,	May require greater investment but offer long-term benefits	
Rely on age-old reliable processes	Rely on experimentation and new methods and practices	
It doesn't prioritise the circular economy or resource efficiency	It creates a closed-loop system where waste is used as a resource	
It doesn't consider the long-term impact of waste disposal and may not be transparent	It aims to be sustainable and environmentally conscious while being transparent and accountable to stakeholders	

67.3 Innovative Value-Added Products

Waste paper is a major problem that affects the environment and economy of countries around the world. It is estimated that millions of tons of waste paper are generated annually, and the majority of this waste is either burned, buried, or ends up in landfills. This not only creates environmental pollution but also leads to the depletion of natural resources such as trees, which are the primary source of paper production. However, in recent years, there has been a significant shift in the way waste paper is being viewed—from a problem to an opportunity. Innovative ways are being explored to utilise waste paper in creating value-added products, which is not only reducing waste but also creating new business opportunities and contributing to a circular economy. One of the most popular ways waste paper is being utilised is through recycling. Waste paper can be recycled into new paper products, such as packaging materials, newspapers, magazines, and tissue paper. The recycling process involves collecting, sorting, and processing waste paper into pulp, which is then used to manufacture new paper products. Recycling not only saves trees but also reduces the amount of waste sent to landfills and helps to conserve energy and water, which are used in the paper-making process (Shang et al., 2021; Chandra et al., 2021).

Another innovative way waste paper is being utilised is in the production of eco-friendly building materials. Waste paper is combined with other materials, such as cement or clay, to create building blocks, insulation, and roofing materials. These products have excellent insulation properties and are lightweight, which makes them ideal for use in eco-friendly construction projects. The use of waste paper in building materials not only reduces waste but also helps to lower the carbon footprint of buildings and contributes to a more sustainable construction industry. In addition to building materials, waste paper is also being utilised in the production of fuel pellets. These pellets are made by compressing waste paper into small pellets, which can be used as a fuel source for heating or cooking. The use of waste paper pellets as fuel not only reduces waste but also provides an alternative to traditional fossil fuels, which are a major contributor to greenhouse gas emissions (Bhargava et al., 2020; Yue et al., 2022).

Waste paper is also being utilised in the fashion industry, where it is used to create unique and innovative textile products. Waste paper is transformed into a pulp, which is then spun into fibres and woven into fabrics. These fabrics are not only eco-friendly but also have unique properties, such as being water-resistant and durable. Waste paper textiles can be used to create a range of products, from clothing to home textiles, and are a great way to reduce waste in the fashion industry. Another innovative way waste paper is being utilised is through the production of biodegradable packaging materials. These materials are made by combining waste paper with other natural materials, such as starch or cellulose, to create packaging that is not only eco-friendly but also biodegradable. Biodegradable packaging materials are becoming increasingly popular as businesses look for ways to reduce their environmental impact and meet consumer demand for sustainable products (Fuller et al., 2006; Gomes et al., 1992).

Chapter 36
Management of Floral Waste, as Well as Various Techniques and Approaches for Converting the Floral Waste into Value-Added Products

Chittepu Obula Reddy and Valluru Saileela Sirisha

Abstract Flowers add an aesthetic feel to any celebration and are thus commonly used for decoration. They are also used to make perfumes, food products, cosmetics, textiles, and other items. Flowers used for decoration or ritualistic practices are frequently not disposed of properly. Flowers, like other waste, find their way into the garbage or are discarded as waste, either into water bodies or left out in the open, causing a variety of environmental problems. Disposing of them on land or in nearby bodies of water causes significant pollution. Though disposing of waste on land is beneficial in some ways, when done improperly, it causes unpleasant odors and attracts pests and insects that may carry pathogens. During decomposition, they also emit greenhouse gases such as methane, which contributes to environmental pollution. The disposal of flowers in rivers, oceans, and other bodies of water pollutes the water and harms aquatic life. However, with increasing knowledge in sustainable development and waste management, various techniques have been employed to convert the floral waste into value-added products like pharmaceutically active components, compost, biofuels, biogas, bioethanol, organic acids, pigments, dyes, food products, incense sticks, handmade paper production, etc. are discussed in this chapter. Various technologies involved and innovative approaches for floral waste management have been discussed in this chapter.

Keywords Floral waste · Cosmetics · Disposal · Pharmaceutically active components · Biofuels · Organic acids

C. O. Reddy · V. S. Sirisha (✉)
Department of Biotechnology, Chaitanya Bharathi Institute of Technology, Hyderabad, Telangana 500075, India
e-mail: vallurusaileelasirisha@gmail.com

C. O. Reddy
e-mail: cobulreddy_biotech@cbit.ac.in

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36.1 Introduction

Waste can be defined as unwanted or unusable material. Waste can be either in the solid state, liquid state, or gaseous state. Solid waste disposal and management techniques remain a challenge to date. Based on the origin, solid wastes can broadly be classified into organic wastes and inorganic wastes. Organic waste is waste of biological origin while inorganic waste is from a non-biological origin, say industrial or a result of any non-natural process. Examples of inorganic wastes include metals, electronic waste, synthetic compounds like plastic, Teflon, batteries, glass, etc. The main sources of organic waste are typically composed of food, excrement produced by living organisms like humans and animals, flowers, sewage, leaves, paper, and agriculture. Unfortunately, these types of wastes are often burned or carelessly disposed of in open areas, which can cause a range of negative impacts on the environment such as soil degradation, air pollution, and water contamination. Moreover, the potential health risks associated with improper waste management practices on the part of humans are significant (Srivastav et al., 2021).

36.2 Significance of Floral Waste Management

Flowers add an aesthetically pleasing element to any celebration and are thus frequently used for decoration. They hold a significant place in various religious, cultural, and social ceremonies as they are regarded as holy entities and are offered to the idols of deities. They are used in making perfumes, cosmetics, food products, textile industry, and pharmaceutical industry as well. Most of the manufacturing processes use flowers to extract the phytochemicals and thus generate a lot of floral waste. Floral waste accounts for the used flowers, the stems, and the wilted leaves associated with them. It is estimated that the European Union (EU) accounts for approximately 44% of total flower production worldwide, with the Netherlands alone accounting for roughly one-third of total production (Abeliotis et al., 2016). India, the country with the most floriculture land area, produced approximately 1641 t of loose flowers and 477 lakh cut flowers in 2014–15 (Horticulture-Statistical Year Book India 2016). Due to a lack of amenities such as cold storage facilities, 40% of total flower production in developing countries such as India and Sri Lanka goes unsold and is wasted. According to one study, the amount of FW produced per day in India is approximately 4738 t (Sharma et al., 2016). According to (Arici et al., 2016), Turkey produces approximately 50 t of tulip petal waste annually (Dutta et al., 2021).

36.3 Challenges Faced by the Traditional Approaches

Floral waste is one of the most overlooked forms of solid waste. The degradation of flowers is a slow process. Flower merchants have been found to dispose of their waste improperly, often leaving it on the streets. This not only creates a nuisance with pests being attracted to the garbage, but it also poses a serious risk of an outbreak of diseases. In rainy seasons, the situation becomes even worse as mosquitoes and flies breed on the waste, creating potential health hazards. Furthermore, unattended cattle might feed on floral waste and might be affected by diseases. While the likelihood of such occurrences may be relatively low, if left unattended, this waste may become the source of epigenetic changes in the living organisms nearby. Another significant concern is the production of leachate from discarded flowers, which poses a serious threat to public health if it mixes with river water or well water. It also serves as an agent for soil pollution, surface water pollution as well as groundwater pollution. Therefore, it is important to properly manage floral waste and ensure that it does not accumulate in areas where it can have adverse effects. This may involve implementing measures such as regular cleaning, waste disposal, or repurposing them into value-added products to minimize the risks associated with unattended floral waste (Waghmode et al., 2018).

36.4 Significance of Floral Waste as a Resource

Initially, waste was viewed as a cost, with landfilling being the most common management method, but there has been increasing recognition of its potential value. FW has several properties, including a high sugar content, a pleasant aroma, and a lovely color, and it can be recycled into several value-added products. Flower waste can be managed by turning it into consumable herbal products like incense sticks, perfumes, interior decorative items, natural colors for cotton and silk products, composts, biogas, and so on (Fig. 36.1). Some researchers have developed environmentally friendly bio-sorbents to remove toxic dyes and heavy metals from aqueous solutions using flower petals. FW samples were also found to be high in cellulose (22.31–37.22%) and hemicellulose (19.19–38.89%) content and low in lignin content (1.76–4.54%) (Srivastav et al., 2021). Various phytochemicals present in the flowers account for distinct biological activities like antimicrobial effect and anti-inflammatory effect (Table 36.1).

36.4.1 Biofuels

Biofuels are becoming increasingly popular as a renewable alternative fuel source. When compared to traditional fossil fuels, biofuels have the potential to improve air

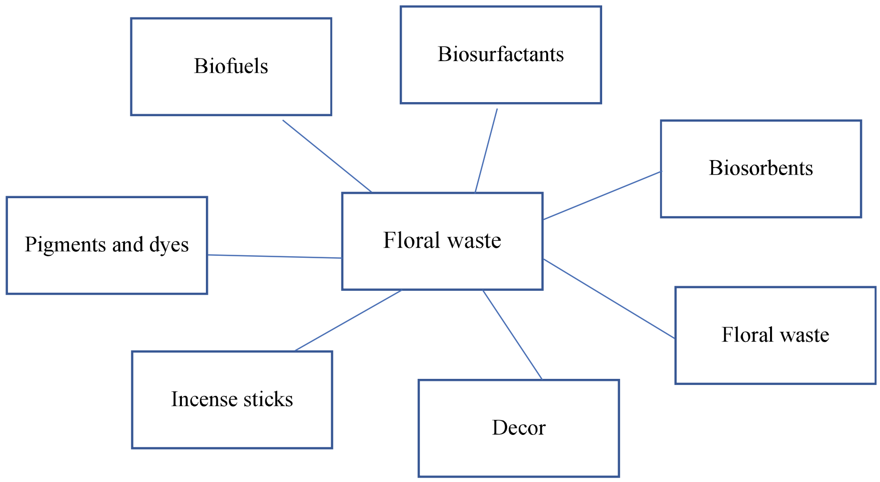

Fig. 36.1 Flowchart depicting applications of floral waste in various domains

Table 36.1 Different phytochemicals present in the flowers and their activity

Flower	Phytochemicals	Properties	References
Origanumscabrum Origaummicrophyl	Carvacrol, terpinen-4-ol, linaloolo, sabinene, terpinene	Antimicrobial	Aligiannis et al. (2001)
Rosmarinusofficinalis	2, 3-diphenyl-2-picrylhydracyl hydrate (DPPH), carnosic acid, rosmarinic acid	Antimicrobial activity	Jadhav et al. (2013), Moreno et al. (2006)
Achillea ageratum	B-sitosterol, stigmasterol	Anti-inflammatory activity	Gomez et al. (1999)
Pyrethrum		Pest repellent	Qiu et al. (1998)

quality. They emit fewer harmful pollutants such as sulfur dioxide, particulate matter, and nitrogen oxides, all of which contribute to air pollution and respiratory diseases. The use of biofuels in transportation and other industries can help to reduce air pollution and improve public health. Since floral waste might be rich in lignocellulosic material, it makes it a good source of energy. Using these waste streams to produce biofuel aids waste management by reducing the need for landfilling or incineration. It adds value to these waste materials and helps to create a circular economy (Kumar et al., 2020).

36.4.1.1 Bioethanol

Flowers contain sugars that easily be converted to ethanol. A simple fermentation reaction includes the conversion of carbohydrates into alcohol. The most common sugars present in floral waste include sucrose, fructose, glucose, disaccharides, and other monosaccharides like hexose. These sugars are usually concentrated in the lower part of the plant though nectarines are present in various parts of the plant. But for us to access these sugars to produce alcohol, we must aim in breaking down the lignin structure that can help the enzyme easily access the cell wall. This helps speed up the process during the hydrolysis. During hydrolysis, the cellulose chains between complex sugars are broken down to produce simpler ones.

Since the substrate is floral waste instead of flowers themselves, the mixture must first be washed and then any other objects other than the organic waste must be separated. Upon separation, the mixture is to be autoclaved to kill any potential pathogens and make it free of microorganisms. The substrate is treated with an alkaline sodium hydroxide solution and is boiled. The mixture is subjected to enzyme hydrolysis. After cooling to adequate temperatures, an inoculum of fermenting microbes like *Saccharomyces cerevisiae* is added to carry out the process of fermentation. The ethanol can be separated from the broth using basic down-streaming techniques such as filtration followed by distillation. Upon further purification steps, bioethanol can be obtained. The ethanol yields depend on the type of microorganism employed and conditions for fermentation, including nutrients, oxygen, pH, and temperature, were used during the conversion of sugars (Khamee et al., 2021).

It has been shown that the utilization of the mahua flower as a substrate for the production of ethanol through submerged fermentation is of great economic advantage. A study has been done on biogas production using floral wastes as raw material (Mohanty et al., 2009). There is a report on biogas production from rose by anaerobic digestion in a batch reactor. The biogas from floral waste can be used for electricity generation and as a fuel (Ahmed et al., 2021). Though the production of alternative fuels using floral waste seems promising, the cost of production seems to be high and the carbon footprint left by industries is no more different than using normal fuels. Hence, better technologies must be established to get a better product.

36.4.1.2 Methane

Biogas, primarily composed of methane, is generated through a process called anaerobic digestion. This process involves the breakdown of various organic waste materials by different species of microorganisms in an oxygen-deprived environment. During anaerobic digestion, the input organic material is decomposed into a mixture of methane and carbon dioxide, commonly known as biogas. In addition to these primary components, biogas also contains traces of hydrogen sulfide and moisture. Anaerobic digestion consists of several stages, including hydrolysis, acidogenesis, and methanogenesis. The anaerobic digestion process holds significant potential in producing biogas with a high percentage of methane while simultaneously reducing environmental emissions that would otherwise result from the aerobic decomposition of organic waste materials. Methane enrichment in biogas is crucial for enhancing its heating value and making it suitable for multiple applications such as vehicular fuel, electricity generation in combined heat and power plants, or even injection into the natural gas grid. By understanding and optimizing this process, we can tap into the vast reserves of organic waste materials to create clean, sustainable energy sources and minimize the adverse environmental consequences arising from conventional waste disposal methods (Kulkarni et al., 2019).

36.4.2 Compost

Domestically, people dispose of the floral waste generated in small quantities in their gardens. Though this might be helpful to some extent, the biological processes such as composting followed by vermicomposting to convert floral waste into useful organic fertilizer would be of great benefit. Hence several techniques have emerged to treat floral waste as compost. Both composting and vermicomposting are aerobic processes. The floral waste is washed and homogenized to form a uniform mixture. Since composting only floral waste takes time to compost, other eco-friendly additives like the excreta of cattle, coconut coir, and small amounts of soil can help fasten the process. Also, various factors like temperature, moisture, pH, humidity, etc., are the factors affecting the efficiency of the compost mixture. It is to be noted that the moisture content of the mixture must be monitored to enhance the quality of the compost and also prevent any unwanted microbial growth. Other factors like the carbon to nitrogen ratio must be optimized. The mixture must be mixed and aerated for optimum results. Many studies show that the excreta of cattle enhanced the quality of the compost consortia (Shouche et al., 2011).

Vermicomposting is an advantageous method for managing organic waste. However, the quality of the compost depends on the initial composition of the waste. To develop a better formula, statistical tools like RSP (Response Surface Methodology) or ANN (Artificial Neural Networks) can be used. Composting is one of the most efficient ways of managing floral waste but is a time-consuming process. Composting floral waste not only saves organic material from the landfill, but also creates a valuable resource that improves soil fertility, promotes plant growth, and promotes a sustainable gardening practice (Sharma et al., 2021).

36.4.3 Food Products

When it comes to food products, floral wastes as such cannot be used in the industry instead, the unused parts during a production process can be used. It is widely known that the production of saffron, a highly prized spice, results in an enormous amount of flower waste, as only the stigma is utilized. Recent research, however, has uncovered the potential of saffron flower extracts, which contain anti-oxidative properties, to be used in preserving various food products such as yogurt. This is attributed to the presence of biologically significant components like flavonoids and anthocyanins that possess these antioxidant properties (Cerda et al., 2023).

Moreover, phenolic compounds, which are also present in saffron flower extracts, have been found to play a vital role in human nutrition due to their numerous functional and food-related biological properties. These include antioxidant, anti-inflammatory, anti-carcinogenic, anti-diabetic, and anti-hypercholesterolemic activities, among others. Therefore, the use of saffron flower extracts not only addresses the issue of waste generated during saffron production but also offers a promising opportunity to utilize its remarkable health benefits in various food applications. The incorporation of these valuable compounds into food products could lead to enhanced health benefits for consumers while aiding in sustainable production practices (Mejri et al., 2020).

Mahua flower waste can be used for the production of syrups presents an eco-friendly and sustainable solution in the food industry. The process begins with collecting and drying the mahua flower waste, which is then solubilized in water to facilitate the extraction of their components. Following this, the solution undergoes a decolorization process involving slaked lime and activated charcoal, which plays a key role in purifying and improving the overall quality of the liquid. The mixture is then concentrated to achieve an ideal consistency and flavor profile, resulting in a delicious and versatile syrup. This approach not only promotes the sustainable use of resources but also opens doors for further exploration in upcycling floral waste products to derive value-added food items (Waghmode et al., 2018).

36.4.4 Biopesticide

Biopesticides are a natural and environmentally friendly alternative to synthetic chemical pesticides, as they are derived from various sources such as plants, flowers, and microorganisms. One such example of an effective biopesticide is found within marigold flowers. Marigolds possess the ability to significantly reduce nematode populations in the soil. In addition to marigolds, other plants like chrysanthemum species can be used as a source of biopesticides. Pyrethrum is a widely used biopesticide derived from the flowers of *Chrysanthemum cinearifolium* and *Chrysanthemum coccineum.* Effective in controlling common pests such as fleas, mosquitoes, moths, and ants, pyrethrum offers a safe and eco-friendly alternative to conventional pesticides (Chaudhary et al., 2022).

The process of obtaining pyrethrum from chrysanthemum flowers involves collecting the waste flowers, trimming them into small pieces, and soaking them in water for several hours. Afterward, this infused water is sprayed onto plants' surfaces or drenched into their root zones to effectively control unwanted pests with minimal environmental impact. As biopesticides like those derived from marigold and chrysanthemum flowers continue to gain attention in sustainable agriculture practices, they offer a promising solution for reducing our reliance on harmful chemical alternatives while protecting the health of our plants and ecosystems.

36.4.5 Biosurfactants

The accumulation of unattended floral waste creates a breeding ground for numerous microorganisms, presenting a unique opportunity for further research and exploration. By isolating these microorganisms, we can potentially identify their diverse properties and examine how they may be utilized in the manufacturing process of various products. This innovative approach to repurposing floral waste not only offers significant ecological benefits but also paves the way for discovering new applications in fields such as biotechnology, pharmaceuticals, and agriculture. As scientists continue to delve deeper into these microorganisms' functions, the possibilities for enhancing existing products or developing novel solutions in multiple industries become increasingly attainable. In turn, this fosters sustainability and encourages the responsible management of floral waste resources.

In a recent study focusing on nectar Pseudomonas isolates, it was discovered that four out of the eight isolates were capable of producing biosurfactants (Ben et al., 2015). Biosurfactants, the remarkable microbial amphiphilic molecules, possess notable surface-active and biological properties that make them highly applicable to a diverse range of industries and processes. These extraordinary molecules are synthesized by microbes, particularly during their growth on water-immiscible substrates, thus offering an eco-friendly alternative to conventionally synthesized chemical surfactants. In recent years, biosurfactants have gained significant attention due to their inherent biodegradable nature, low toxicity levels, environmental acceptability, and capacity to be produced using renewable and relatively inexpensive substrates. Consequently, they have found extensive applications across various sectors including pharmaceuticals, cosmetics, petroleum production, and the food industry. Research has explored the potential of producing biosurfactants using domestic vegetable oils as a means to transform renewable resources into higher value products. Interestingly, these studies have demonstrated better growth and glycolipid production when utilizing natural vegetable oils in comparison to more complex media or hydrophobic carbon sources. The continued advancements in biosurfactant technology hold great promise in revolutionizing multiple industries while focusing on sustainable development for a greener future (Makkar et al., 2002).

Biosurfactants have strong antibacterial, antifungal, and antivirus activity, as well as acting as antiadhesive agents to pathogens, making them useful in the treatment of many diseases, as well as therapeutic and probiotic agents (Gharaei, 2011). Not only do they demonstrate potential in combating a wide array of diseases, but they also serve as effective antiadhesive agents, preventing pathogens from binding to host cells and tissues. The production of surface-active compounds by *Microbispora* sp.

V2 using flower extract of *Madhuca latifolia* L has been studied, where the surface-active compound produced possessed biosurfactant properties (Waghmode et al., 2015). The cell-free supernatants of *Madhuca latifolia* flower extract medium with 20 μg ml^{-1} of anthracene reduced the surface tension to 35%. The study showed that the use of *Madhuca latifolia* L. flowers can be a potential bioresource for the production of exopolysaccharides having surface active properties (Waghmode et al., 2015).

36.4.6 Pigments and Dyes

In recent years, environmentally conscious choices have gained significant importance, particularly in the field of textiles and fashion. One such sustainable method of textile coloration is the use of natural dyes derived from floral sources. In a study conducted by Teli et al. (2013), researchers delved into the potential of extracting natural dyes from two vibrant and abundant floral sources—hibiscus and marigold flowers. In their pursuit of devising eco-friendly alternatives, the team examined various natural mordants such as alum, harad, and ferrous sulfate to determine their efficacy in dyeing cotton and cotton/silk blended fabrics. The findings of the study highlighted not only the rich hues obtained from these natural sources but also their compatibility with the chosen mordants, revealing immense possibilities for their application in the textile industry. Furthermore, the environmentally friendly attributes of these plant-based dyes, along with their cost-effectiveness and ease of waste management, make them particularly suitable for large-scale adoption in commercial sectors. Beyond their utility in fabric dyeing, a related study by Eren et al. (2015) identified how these natural dyes derived from rose residues can enhance the functionality of dye-sensitized solar cells, paving the way for innovations in renewable energy technology while fostering harmony between industry practices and sustainable living. The saffron flower waste was used for extraction of natural dye that produced bright greenish yellow and green color pashmina fabric at acidic pH and also found that the fabric dyed at an acidic pH without mordant has anti-microbial efficiency against Staphylococcus aureus (Raja et al., 2012; Jadhao & Rathod, 2013) worked on the extraction of patuletin dye from French marigold flower waste generated from temple and they found that the high antioxidant capacity in the catechol was observed in patuletin dye wherein in industries it is thrown to river generally and reported that as compared to catechol, the patuletin dye is easily degradable, low cost, and has no hazardous effect (Bennurmath et al., 2021).

The petal part of the saffron flower, for example, has been effectively utilized to extract dye for application on luxurious Pashmina shawls, as reported by (Raja et al., 2012). Additionally, research has indicated the potential of using waste from hibiscus flowers as a natural dye in textile coloration. Similarly, safflower petals contain approximately 30% yellow and 0.83% red pigments, making them suitable for various applications including staining, stabilizing beverages and cosmetics, printing, dyeing, and natural food colorants. The exploration and adoption of floral sources for natural dyes offer great potential to reduce environmental impact while maintaining the vibrant colors that have long been associated with exquisite textiles (Adhikary, 2021).

The utilization of tulip extracts in the food industry has been a topic of discussion in recent years, particularly with regard to their potential impact on human health. However, research conducted by (Sagdic et al., 2013) has shown that there is no cause for concern when using these extracts as food additives or colorants. In their study, it was found that the orange red, pink, and violet extracts exhibited no cytotoxic activity against MCF-7 cell lines, which indicates that these substances are not harmful to our well-being. As such, there is a clear basis for continuing the use of tulip extracts within the food industry and further exploration of their potential applications. One aspect that warrants attention is the enhancement of extraction yields; doing so would contribute to greater economic returns for businesses involved in tulip-derived products. Therefore, researchers and industry professionals should focus on refining extraction techniques to maximize yields, ultimately leading to enhanced profitability and driving the continued growth of this niche market segment within the food industry at large (Arici et al., 2016).

36.4.7 Biosorbents

Preparing biosorbents from floral waste has proven highly effective in tackling the pervasive issue of harmful dye removal from wastewater. This innovative method not only presents a sustainable alternative to conventional methods but also successfully reduces the cost factor often associated with such processes. By utilizing natural materials readily available in the environment, these biosorbents produced from waste provide a unique way to combat water pollution, while simultaneously minimizing adverse effects on surrounding ecosystems. Moreover, as these compounds are organic, their biodegradable nature diminishes potential risks of further contamination or environmental harm. Flowers are shown to have phytochemicals effective in the bioremediation of heavy metals like chromium, mercury, and zinc (Table 36.2).

36.4.8 Incense Sticks

Incense sticks hold a significant position in the daily lives of many Asian households especially Indians, serving as an essential element during prayer ceremonies and rituals. The role of incense sticks in these traditions cannot be overstated; without them, the sacred rites of puja would be deemed incomplete. After being used in worship, the flowers are collected and separated. They then undergo a careful process of drying and grinding, transforming them into fine powders. This mixture serves as the foundation for high-quality incense sticks, which are then skillfully crafted to elevate the spiritual atmosphere during prayer ceremonies (Dasalukunte et al., 2023).

Table 36.2 Different flowers used as biosorbents in removing various heavy metals

Flower	Bioremediation	References
Borassus aethiopum (Palm flower)	Chromium	Elangovan et al. (2008)
Rose biomass	Chromium, mercury, zinc	Aman et al. (2018)
Marigold	Cadmium, chromium	Mondal et al. (2015)
Typha latifolia	Pesticide residues (diazinon, atrazine, chlorothalonil, ametrine, chlorpyrifos, etc.)	Tolcha et al. (2020)
Floral waste	Color from textile effluents	Elango and Govindasamy (2018)

36.5 Conclusion

The tremendous potential of floral waste often goes unnoticed, however, exploring the rich opportunities it presents can lead to the creation of a diverse array of sustainable and eco-friendly products. One such example is handmade paper, which utilizes floral waste for its raw materials and offers a beautiful, artistic alternative to traditional paper. Additionally, the world of interior design can benefit from resin art made with used flowers, providing an innovative and aesthetically pleasing approach to home decor. Greeting cards incorporating the vibrant colors and textures of repurposed flowers can breathe new life into an age-old tradition. Moreover, the fragrance industry can extract essential oils from floral waste for use in soaps and perfumes, further reducing environmental impact while crafting luxurious and uniquely scented products. Embracing the possibilities presented by floral waste not only serves to minimize our carbon footprint but also allows for the development of novel, eco-conscious items that enhance our daily lives.

As discussed in the chapter, in addition to their visual appeal, flowers find several other uses in the production of perfumes, food items, cosmetics, textiles, and many other products. However, the disposal of these blooms after they have fulfilled their intended purpose often poses a significant challenge. We have seen how improper disposal methods, such as discarding them in the garbage or throwing them into open spaces or water bodies, can lead to an array of environmental problems. Pollution becomes a major issue when flowers are carelessly discarded on land or in aquatic environments. On land, improper waste disposal often leads to unpleasant odors and attracts pests and insects that may carry various pathogens. Additionally, decomposing flowers release greenhouse gases like methane which contribute to air pollution and climate change. Similarly, when disposed of in rivers, oceans, and other bodies of water, floral waste pollutes the water and causes harm to aquatic life.

Nonetheless, as global awareness regarding sustainable development and effective waste management continues to grow, numerous techniques have been developed to transform floral waste into valuable products. By employing these innovative solutions, floral waste can be repurposed into useful items such as pharmaceutical products, compost, biofuels, biogas, bioethanol, organic acids, pigments and dyes, biosurfactants, syrups, biosorbents, substrate medium for microbial growth, production of organic acids, decor, etc. Furthermore, discarded flowers can be utilized in food production processes as well as serve as raw materials for incense sticks and handmade paper industries. These advanced approaches to waste management that focus on conserving resources and minimizing pollution at each stage of flower processing from cultivation to disposal can be achieved while also protecting our planet.

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MICROPROPAGATION OF MEDICINAL PLANTS

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CHAPTER 10

In Vitro Protocols for Micropropagation of *Catharanthus roseus* (L.) G. Don

Govindugari Vijaya Laxmi[1,*] and **K. Dharmalingam**[1]

[1] *Department of Biotechnology, Chaitanya Bharathi Institute of Technology, Hyderabad, Telangana-500075, India*

Abstract: *Catharanthus roseus* (*C. roseus*) is an important alkaloid-yielding medicinal and ornamental plant belonging to the family Apocynaceae. The genus *Catharanthus* is well studied and reported to contain biologically active terpenoid indole alkaloids (TIAs) with over 130 compounds isolated and identified. It has great medicinal importance in treating various ailments to treat diseases as diabetes, malaria, menorrhagia, Hodgkin's disease, *etc*. In view of the immense importance in the pharmaceutical industry, micropropagation of *C. roseus* has been the best alternative for continuous source of plants and also for *in vitro* production of secondary metabolites. Various explants have been studied for micropropagation; however, nodal explants were the most suitable. For surface sterilization, 0.1% $HgCl_2$ or 70% ethanol, followed by sodium hypochlorite and Bavistin (carbendazim), was optimum to control the microbial contamination. Murashige and Skoog (MS) medium was the most widely used for its success rate. 2,4-D for callus initiation and BAP, along with zeatin and activated charcoal, were reported to be promising for regeneration of plantlets. The 100% acclimatization of plantlets on transfer to field depends on the soil mixture and environmental conditions and humidity in the initial stages of transfer from *in vitro* cultures.

Keywords: Acclimatization, *Catharanthus roseus*, *In vitro* Studies, Micropropagation, Organogenesis, Plant Regeneration, Somatic Embryogenesis.

INTRODUCTION

Catharanthus roseus (L.) G. Don, commonly known as Madagascar periwinkle, is an important medicinal plant. It belongs to the family Apocynaceae. It contains several commercially valuable secondary metabolites, making it the most demanding medicinal plant. The secondary metabolites are used in the treatment of various ailments and disorders like Hodkin's disease, lymphoblastic leukaemia, breast and skin cancer and cancerous tumours [1]. The periwinkle has been repor-

* **Corresponding author Govindugari Vijaya Laxmi:** Department of Biotechnology, Chaitanya Bharathi Institute of Technology, Hyderabad, Telangana-500075, India; Tel: +91-040-24193276; E-mail: drgvlaxmi_biotech@cbit.ac.in

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RECENT ADVANCES IN THE APPLICATION OF MARINE NATURAL PRODUCTS AS ANTIMICROBIAL AGENTS

Editors:
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Ramanathan Srinivasan
Arunachalam Kannappan

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CHAPTER 8

A Recent Update on Sponge Bioprospecting and its Antimicrobial Properties: Their Biological Mode of Action

Balraj Sudha[1], Kanagaraj Suganya[1], Bishwambhar Mishra[2], Govindugari Vijaya Laxmi[2], Sanjeeb Kumar Mandal[2,*], Sanjay Kumar[3] and Sundaravadivelu Sumathi[1]

[1] *Department of Biochemistry, Biotechnology and Bioinformatics, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore-641043, Tamil Nadu, India*

[2] *Department of Biotechnology, Chaitanya Bharathi Institute of Technology, Hyderabad-500075, Telangana, India*

[3] *Department of Biochemical Engineering and Biotechnology, Indian Institute of Technology, Delhi-110016, India*

Abstract: In recent decades, both the growing global resistance to existing antibiotics and the shortage of new groups of compounds identified have become a public health concern. In order to solve it, researchers are now focusing their attention on unconventional sources, including microbes from harsh environments. In this context, the aim of this study was to determine whether marine sponges have the ability to inhibit the growth of microorganisms that are terrestrial in origin and pathogenic to humans. The majority of these chemicals have so far been found in marine invertebrates, primarily sponges. Marine sponges are a rich source of structurally specific natural substances, some exhibiting a diverse variety of biological activities. Also, excellent sponge drug candidates are often overlooked because the sponges are either rare or difficult to obtain, or both. Sponges have piqued the interest of scientists who want to learn more about the associated microbial community and the useful metabolites they produce, which can be used in pharmaceutical and biotechnological applications. The ecological importance of mutualistic relationships between marine sponges and their related microbes cannot be overstated. These bioactive compounds from microbes protect their hosts from a variety of microbial diseases. These results indicate that the antimicrobial properties of marine sponge extracts may be used as a complementary or replacement method for treating microbial infections.

* **Corresponding author Sanjeeb Kumar Mandal:** Department of Biotechnology, Chaitanya Bharathi Institute of Technology, Hyderabad-500075, Telangana, India; Tel: +91 9344449074, E-mail: sanjeeb.vit@gmail.com

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Chapter three - Reactive distillation and reactive separations

Mallaiah Mekala [1], Srinath Suranani [2]

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Abstract

Reactive distillation (RD) is a method where the reaction and the separation cooccur. This is one of the best intensified procedures. The present chapter aims to discuss the mathematical model for RD. The various kinetic models have addressed the formation of the rate equation in the reactors. The RD process can use the kinetic rate expression. For the temperature and composition profiles, the esterification of acetic acid with methanol has been discussed in the form of a case study. There is another case study regarding the esterification of acetic acid with ethanol. The temperature and composition characteristics of acetic acid and ethanol esterification to yield ethyl acetate have been studied. The profiles in the synthesis of methyl acetate and ethyl acetate have been determined as a function of the number of steps. The basic principles of reactive dividing wall columns and enzymatic RD and their advantage over RD are reviewed. The chapter also discusses about the reactive extraction and absorption methods.

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Functional Coatings for Biomedical, Energy, and Environmental Applications

Chapter 11

Green-Synthesized Nanomaterial Coatings for High-Performance Electrodes

D. Shruthi Keerthi, M. Mukunda Vani, Balaji Krishnamurthy

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Summary

Increasing demand for clean and renewable energy due to environmental impact and demand for advanced implantable and portable electronic devices motivate the need for developing technologies that can harvest energy at an affordable cost. Pencil graphite leads can be a promising electrode material due to its background currents, sensitivity, cost-effectiveness, and ease of disposal when compared to conventional electrodes. This work focuses on developing a simple method to deliver high-performance pencil graphite electrodes (PGEs) by coating green synthesized nanomaterials onto pencil leads. Green synthesized nanomaterials prepared from natural plant-based sources like *Azadirachta indica* (neem), *Rosa indica* (rose), and *Ocimum tenuiflorum* (basil) are coated to modify the surface of the pencil lead, which renders better electrochemical activity. This iron nanoparticle (NP)-coated PGEs (FeNP/PGE) from rose and neem extract exhibited good conductivity when compared to the bare and treated PGEs. The polarization curves obtained from cyclic voltammetry resulted in an open circuit potential (OCP) of 0.648 V for (FeNP/PGE) from rose extract when compared to bare (0.492 V) and treated (0.532 V), respectively. The maximum current density was obtained for FeNP/PGE from *R. indica* (1484.8 μA cm $^{-2}$). Hence, FeNP/PGE (rose extract) electrode exhibits fast electron transfer kinetics and proved to be a better-modified electrode and exhibits high performance.

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7 - Stimuli-responsive polymer nanocomposite films and coatings

B.V.S. Praveen [1], Raj Kumar Verma [1], Appala Naidu Uttaravalli [2], Bhanu Radhika G. [2], Sai Narender Sakhamudi [2 3]

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Abstract

Polymer nanocomposite (PNC) represents the reinforcement of polymer matrix using nanosized additives. These PNCs are becoming a common approach for enhancing polymer matrices' stiffness and mechanical strength. PNCs' high surface-to-volume ratio allows them to outperform micro- and macrocomposites. Incorporating stimuli functions into these materials is gaining popularity as a new generation of advanced polymer-based nanomaterials. Stimuli-responsive PNCs are mobile and can respond to internal or external stimuli. Stimuli-responsive polymer nanocomposite films and coatings are a challenging research area in the technological community, with better future applications available for several decades. Applications such as coatings, controlled drug delivery, self-repair, and self-healing behavior, and other applications based on biomedical devices have benefited from using these polymer nanocomposite coatings and films. This chapter outlines the concept of PNCs, the importance of stimuli responsiveness, the preparation of PNC coatings and films, and the change in properties of PNCs when subjected to stimuli responsiveness and applications thereof.

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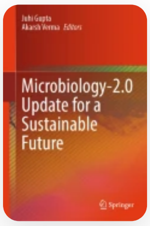

Microbiology-2.0 Update for a Sustainable Future

Vishnu A. Gite, Raj K. Verma & Ratna S. Katiyar

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Abstract

Knowledge of molecular mechanisms (MM) has been attracted globally due to its potential application in the field of drug delivery. In the past decades, several MM methods were identified with an extensive range of excipients for the reason of poor solubility of drugs. The MM has been scrutinized with complex formulations where the drugs are encapsulated into responsive excipients so that the drug delivery process has to be improved. This review gives brief information on mechanisms used in drug delivery such as swelling, diffusion, and erosion. In swelling controlled; the drug molecules permeate due to the formation of a hydrogel matrix. Impacting parameters in swelling controlled are temperature pH, light, pressure, ionic strength, magnetic and electric field, etc. In diffusion-controlled; the drug is released via excipient disintegration/cracks/leakages without a change in size. While erosion-controlled

materials erode in the form of monomers and oligomers from excipient on the surface or bulk. These mechanisms depend on drug dose, drug type, quantity and type of excipient, and environmental conditions at the time of drug delivery. It also depends on the geometry and dimension of the administration routes. On the whole, this piece of information is useful to researchers for developing the drug delivery process.

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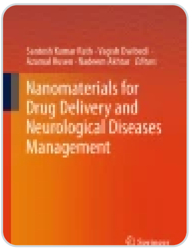

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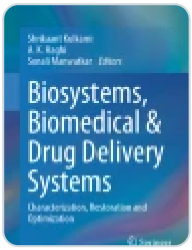

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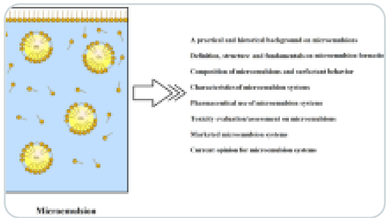

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Author information

Authors and Affiliations

Department of Chemical Engineering, Jawaharlal Nehru Engineering College, MGM University, Chhatrapati Sambhajinagar, 431003, India

Vishnu A. Gite & Ratna S. Katiyar

Department of Chemical Engineering, Chaitanya Bharathi Institute of Technology, Hyderabad, 500075, India

Raj K. Verma

Corresponding author

Correspondence to Ratna S. Katiyar .

Editor information

Editors and Affiliations

Amity Institute of Environmental Sciences, Amity University, Noida, India

Juhi Gupta

Department of Mechanical Engineering, University of Petroleum and Energy Studies, Dehradun, India

Akarsh Verma

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“There are no conflicts of interest to declare by the authors.”

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The authors hereby state that the present work is in compliance with the ethical standards.

Competing Interests

The authors declare no competing interests.

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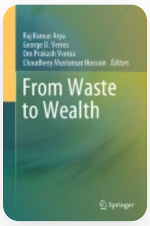

From Waste to Wealth

M. Mukunda Vani, D. Shruthi Keerthi & P. R. Redapangu

440 Accesses

Abstract

Plastic is a material that cannot biodegrade and is hazardous for the environment since it takes thousands of years to break down. Plastic remains cause acute health issues through land and water pollution. Municipal solid waste contains a considerable quantity of plastic waste in the form of plastic carry bags, sachets, bottles, and primary packaging materials. Recycling, reusing, or converting plastic waste into value-added products has been a topic of attention in the present day in both urban and rural places. One of the sustainable and practical solutions for managing plastic waste is to convert it into plastic bricks that can be applied as building materials. These plastic bricks are lightweight and have higher strength than standard bricks. But, manufacturing pure plastic bricks is

tedious, and a single brick requires large amounts of waste plastic. Thus, an economical way of utilizing plastic waste is to convert it into composite material consisting of cement brick and plastic, 'Poly Brick.' Other than replacing conventional building materials, such as bricks, tiles, concrete blocks, etc., with pure plastic bricks, these composite materials show enhanced properties and renewed strength. Poly Bricks provide the consumer with various benefits, in extension to being eco-friendly. Studies on poly bricks showed enhanced properties such as porosity, compressive strength, tensile strength, chemical reactivity, and durability compared to a standard brick. Many researchers have carried out active research to address the problem of plastic waste by processing it into Poly Bricks. Thus, poly bricks are an excellent alternative to clay bricks, minimizing plastic waste. This chapter discusses the effects of plastic waste, methods for converting the plastic waste into poly bricks, the testing methods, and the comparison of properties of poly bricks with conventional building materials, thus concluding how efficiently the plastic waste converts into value-added products.

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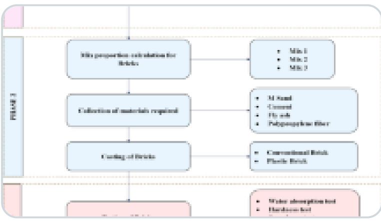

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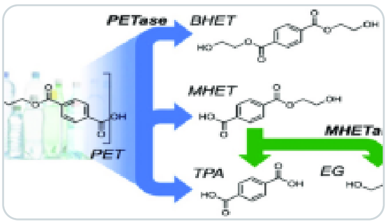

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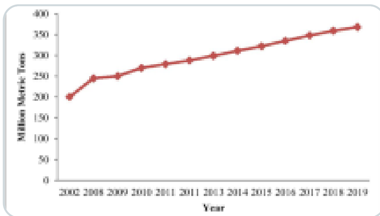

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Author information

Authors and Affiliations

Department of Chemical Engineering, Chaitanya Bharathi Institute of Technology, Hyderabad, 500075, Telangana, India

M. Mukunda Vani & P. R. Redapangu

Department of Chemical Engineering, Anurag University, Hyderabad, 500088, Telangana, India

D. Shruthi Keerthi

Corresponding author

Correspondence to D. Shruthi Keerthi .

Editor information

Editors and Affiliations

Department of Chemical Engineering, Dr. B. R. Ambedkar NIT Jalandhar, Jalandhar, India

Raj Kumar Arya

Department of Chemistry, Aristotle University of Thessaloniki, Thessaloniki, Greece

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Department of Instrumentation and Control Engineering, Dr. B. R. Ambedkar NIT Jalandhar, Jalandhar, India

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Chemistry & Environmental Sciences, New Jersey Institute of Technology, New Jersey, NJ, USA

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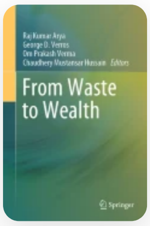

From Waste to Wealth

Vamsi Chirravuri, M. Mukunda Vani & P. V. Naga Prapurna

434 Accesses

Abstract

Fertilizers are an important component added to plants to enhance food production. They provide crops with nutrients like potassium, phosphorus, and nitrogen for their growth. But eventually, The presence of chemicals in fertilizers has an impact on soil fertility and the survival of beneficial microbes. To address this issue, the emergence of biofertilizers has provided a solution. Biofertilizers, which are derived from organic waste, serve as a successor to synthetic fertilizers, given that they are free of any potentially dangerous substances and their ability to enhance soil quality. By utilizing natural products like biofertilizers in agricultural practices, we can protect soil health and ensure the production of high-quality crops. Agricultural wastes like coconut husks, wheat bran, paddy husk, banana stalks, etc. can also be a potential source for K, P, N, and many macro and micronutrients. As banana stalk can be considered a waste recycling product,

fertilizer derived from it is of low cost. It helps degrade pesticide residues, improve soil fertility, and promote plant growth. This can increase the yield by 3.5%, and therefore a rise in economic benefit can be observed. Therefore, this study aims to explain the different production methods of biofertilizers using banana stalk as a feedstock, increase in the nutrient quality, and its effect on enriching the soil fertility. It also provides insight into the potential management of banana waste that can be converted into biofertilizers and the superiority of substituting chemical fertilizer with sustainable organic fertilizer derived from banana stalks.

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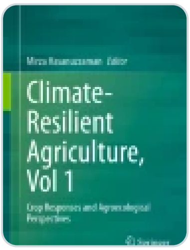

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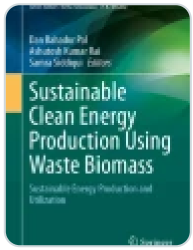

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Author information

Authors and Affiliations

Department of Chemical Engineering, Chaitanya Bharathi Institute of Technology, Gandipet, Hyderabad, Telangana, 500075, India

Vamsi Chirravuri, M. Mukunda Vani & P. V. Naga Prapurna

Corresponding author

Correspondence to Vamsi Chirravuri .

Editor information

Editors and Affiliations

Department of Chemical Engineering, Dr. B. R. Ambedkar NIT Jalandhar, Jalandhar, India

Raj Kumar Arya

Department of Chemistry, Aristotle University of Thessaloniki, Thessaloniki, Greece

George D. Verros

Department of Instrumentation and Control Engineering, Dr. B. R. Ambedkar NIT Jalandhar, Jalandhar, India

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Chemistry & Environmental Sciences, New Jersey Institute of Technology, New Jersey, NJ, USA

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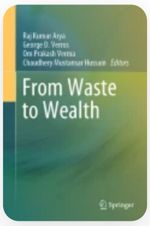

From Waste to Wealth

V. Sravani Sameera, A. V. Raghavendra Rao, Rompicherla Srividya, Karuna Boppena & R. Prasanna Rani

439 Accesses

Abstract

Using animal waste as a valuable resource to produce fertilizers, biogas, bio-oils, and other value-added products has gained significant attention due to its potential to address environmental and economic challenges. This chapter comprehensively overviews the methods and technologies of converting animal waste into these valuable products. It explores the different waste treatment, conversion, and product extraction processes and each approach's potential environmental benefits and economic feasibility. Furthermore, the chapter examines the challenges and limitations associated with the utilization of animal waste and proposes potential solutions to overcome these hurdles. The aim is to

provide readers with valuable insights into the sustainable utilization of animal waste, fostering resource efficiency, and contributing to a circular economy.

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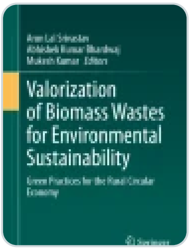

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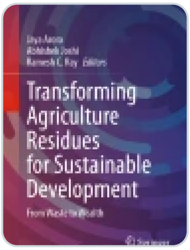

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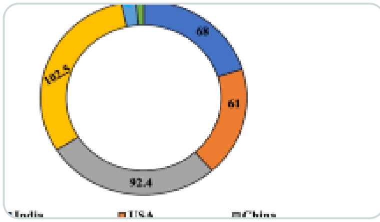

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Author information

Authors and Affiliations

Department of Chemical Engineering, BV Raju Institute of Technology, Narsapur, Medak District, Telangana, 502313, India

V. Sravani Sameera, A. V. Raghavendra Rao, Rompicherla Srividya & Karuna Boppena

Department of Chemical Engineering, Chaitanya Bharathi Institute of Technology, Gandipet, Hyderabad, Telangana, 500075, India

R. Prasanna Rani

Corresponding author

Correspondence to V. Sravani Sameera .

Editor information

Editors and Affiliations

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Chapter 12 Safety first: managing hydrogen in production, handling, and applications

From the book Sustainable Hydrogen Energy

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Abstract

As a versatile energy carrier, hydrogen shows enormous promise in a wide range of applications, including energy generation, transportation, and industrial operations. However, because of its unique properties, including flammability and explosiveness, a full awareness of safety standards is required to mitigate the associated hazards. This chapter thoroughly examines safety, prioritizing it across the whole hydrogen lifecycle, from production to application. It investigates the many techniques of hydrogen creation and the significance of handling with caution due to the potential physiological, physical, and chemical hazards. The chapter emphasizes the importance of risk assessment, effective equipment design, training, and regulatory compliance in assuring safety. To encourage safe hydrogen operation, key safety practices such as system design, leak detection, ventilation, fire suppression, and emergency response planning are presented. The chapter also investigates worldwide safety rules, norms, and standards in controlling hydrogen usage, storage, transportation, and construction codes, while recognizing the need for further progress in the hydrogen supply chain. Education and training, including understanding hydrogen properties, regulatory requirements, risk assessment, emergency response, and ongoing professional development, are critical components for improving hydrogen safety. The hydrogen industry can successfully manage risks, safeguard employees and the environment, and encourage the broad use of hydrogen as a clean and sustainable energy alternative by implementing robust safety procedures.

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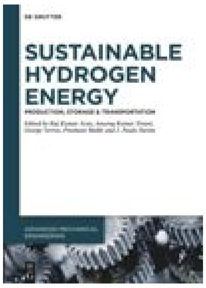

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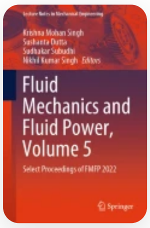

Fluid Mechanics and Fluid Power, Volume 5

(FMFP 2022)

Lokesh Rohilla, Ravi Prakash, Raj Kumar Verma & Arup Kumar Das

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Abstract

Mass transfer during the gas liquid interactions in a monolith reactor has been an area of paramount importance due to its prevalence in process intensification. The present study experimentally investigates the mass transfer from slug bubble train in a glass tube by using the colorimetric method and a high-speed camera. An oxygen sensitive dye resazurin is used with the pure oxygen cap/slug bubble train for the current study. An in-house code has been developed for image thresholding, interface detection, bubble mask generation, and concentration measurement. It is investigated that the overall mass transfer coefficient increases with the gas superficial velocity. The role of the Taylor recirculation vortices in the mass transfer enhancement has been observed from the radial concentration profile.

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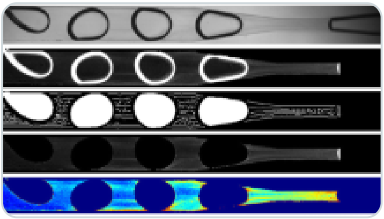

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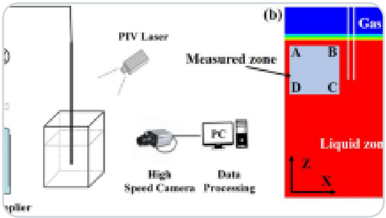

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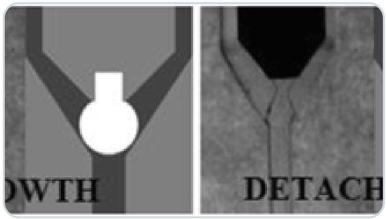

A device for continuous and flexible adjustment of liquid-liquid slug size in micro-channels

Article | 04 February 2020

Abbreviations

d: Tube diameter (m)

\(U_{l}\): Liquid superficial velocity (m s^{-1})

\(U_{g}\): Gas superficial velocity (m s^{-1})

D_L: Diffusivity of Oxygen (m^2 s^{-1})

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Author information

Authors and Affiliations

Process Engineering and Instrumentation Department, CSIR-IMMT, Bhubaneshwar, 751013, India

Lokesh Rohilla

Department of Chemical Engineering, IIT Roorkee, Roorkee, 247667, India

Ravi Prakash

Department of Chemical Engineering, Chaitanya Bharathi Institute of Technology, Hyderabad, 500075, India

Raj Kumar Verma

Department of Mechanical and Industrial Engineering, IIT Roorkee, Roorkee, 247667, India

Arup Kumar Das

Corresponding author

Correspondence to Lokesh Rohilla .

Editor information

Editors and Affiliations

Department of Mechanical and Industrial Engineering, Indian Institute of Technology Roorkee, Roorkee, Uttarakhand, India

Krishna Mohan Singh

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Department of Mechanical and Industrial Engineering, Indian Institute of Technology Roorkee, Roorkee, Uttarakhand, India

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Preface

We are glad to present the book entitled **Technological Developments in Engineering, Management, Arts and Science** to the students, faculty members and researchers of Engineering, Management, Arts and Science. We have observed that eminent professors and active researchers from various technical institutions across the Nation contributed to the book chapters which are focused on state-of-the-art areas related to Electrical and Electronics Engineering, Computing Sciences, Civil Engineering and Mechanical Sciences, Management, Arts and Science.

We hope the readers benefit from the research problems addressed in the book. We are thankful to all the authors and publisher who have helped to bring out the First Edition of the book Technological Developments in Engineering, Management, Arts and Science.

– Editors

Dr. K.A. Emmanuel

Dr. Vallepu Vishnu Vardhan

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Chief Editors

Dr. K.A. Emmanuel
Professor
Department of Chemistry
Y.V.N.R. Government Degree College,
Kaikaluru,
Eluru District-521333. Andhra Pradesh.

Dr. Vallepu Vishnu Vardhan
Professor & HOD
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Hyderabad, Telangana -501 301

Dr. S. Bhargavi Professor
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Department of Electronics and
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SJC Institute of Technology
Chickballapur - 562101 Karnataka

Dr. Ajitharani Unnikrishnan
Assistant Professor
PG and Research Department of
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Sri. C Achutha Menon Government College
Kuttennellur P.O., Thrissur

Dr. Mayank Dave
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Editors

Dr. P. Hima Bindu
Vice Principal/Professor
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Dr. Samapika Das Biswas
Associate Professor
Basic Sciences and Humanities
Institute of Engineering and Management
Kolkata, West Bengal 700091.

Dr. Asmita R. Namjoshi
Assistant Professor
Department of Computer Science
Tilak Maharashtra Vidyapeeth
Mukund Nagar, Gultekdi, Pune - 411037.

Dr. Ajay D. Dahegaonkar
Assistant Professor
Department of Physics Nilkantharao Shiinde
Science & Arts College
Bhadrawati Dis-Chandrapur (M.S.) India
Main Road Bhadrawati

Dr. K. Laxmi Professor
Department of Chemistry
Chaitanya Bharathi Institute of Technology
Gandipet, Hyderabad-500075

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The Elimination of Fluoride Ions from Industrial Wastewater Utilizing Tamarind

Vishnu Vardhan Vallepu

Professor, HoD, MIE, LMISTE, IAENG
Siddhartha Institute of Technology and Sciences (Autonomous)
Department of Civil Engineering

ABSTRACT

Fluoride-related health risks are a major ecological issue across the globe. Drinking water containing fluoride might be advantageous or unfavorable relying on its concentration and total amount devoured. Fluoride fixations between 0.5–1.5 mg/L are valuable, particularly to babies, to forestall dental caries or tooth rot, yet focuses above mg/L reason mottling of teeth. DE fluoridation is commonly completed by adsorption, electrochemical techniques, chemical treatment, dialysis, and particle trade measures. Among them, adsorption is discovered to be powerful and practical. The current examination has been undertaken to create an appropriate agro-based bio-sorbent for DE fluoridation from wastewater. The Tamarind natural product shell was chosen as an appropriate bio-sorbent for disposing of fluoride particles from industrial water to accomplish the desired goal. Tamarind is available naturally and as a waste-product of many organic product mash industries. The current examination exhibited that the Tamarind Fruit shell in natural structure could be utilized as a potential bios orbing specialist to eliminate fluoride particles from industrial water.

Keywords: Fluoride, Tamarind, Adsorption, Bio-sorption.

I. Introduction

Water is the most significant and basic need in traditional everyday life.[1] It is the fundamental life-supporting part. Yet, presently, the more substantial portion of the nations on the planet are confronting the issue of drinking water.[2] Groundwater is one of the significant primary sources for homegrown and horticultural use in India's rural and metropolitan regions. In any case, it is just a local asset in numerous pieces of the nation. In the ongoing years, the constant expansion in the population, financial turn of events, and atmosphere change adversely trouble the nature of water. In a most noticeably awful situation, the blend of the above components may prompt the non-accessibility of surface water in numerous pieces of the nation.[3]

The factory wastewater from different ventures like electroplating, semiconductor, glass, petroleum treatment facilities, etc., contains a high absorption of various natural and inorganic synthetic substances. These poisonous synthetic substances are dangerous and have an unfavorable impact on marine life, similar to earthbound life.[4] Water pollution is a typical issue, too, everywhere in the world.[5] In India, drinking water is discovered to be polluted at numerous spots by various toxins, such as fluorides, iron, nitrates, etc.[2] Fluorides are the dangerous inorganic toxin broadly found in underground water and modern wastewater.[4] Fluorine (F2) is a pale, yellow- green, harmful gas that nearly can't found in regular habitats in natural structures because of its high electro-negativity and reactivity.[6] Fluoride particles in water show novel properties. As its concentration in a proper dosage in drinking water is beneficial to wellbeing and high concentration beyond the prescribed limits influences the wellbeing. High fluoride absorption in the groundwater and surface water in numerous regions of the world is a reason for immense concern.[7] As indicated by different studies, 25 million individuals in 19 states and associated regions have just influenced, and another 66 million are in danger that includes 6 million youngsters beneath the age of 14 years.[8] Different investigations have shown that a high portion and short-term introduction of fluoride can annihilate kidney work. A few exploration bunches detailed that fluoride can meddle with pineal organs' capacity just as the brain. The pineal organ is one of the significant fluoride accumulated sites in the body with high convergence of teeth and bones. The massive absorption of fluoride analyzed bladder disease.[9] Because of all the recently referenced fluoride contaminations and medical conditions that it causes, the World Health Organization (WHO) has indicated the resilience furthest reaches of fluoride substance of drinking water as 1.5 mg/L.[6]

Table 1: Drinking water standards for fluoride prescribed by various authorities[9]

S.No.	***Authorities***	***The permissible limit of fluoride concentration (mg/L)***
1.	World Health Organization (International Standard for drinkingwater)	0.5
2.	US Public Health Standard	0.7-1.2
3.	Bureau of Indian Standards (BIS)	1.0-1.5
4.	Indian Council of Medical Research (ICMR)	1.0-2.0
5.	Central Public Health and Environmental Engineering Organisation	1.0-1.5

The harmful impact of the overabundance measure of fluoride in the drinking water of a few towns in the Ethiopian Rift Valley has been proved since the 1970s because the people in these zones were acclimated to drinking water that contains fluoride.[10]

II. The Different Benefits and Harmful Effects of Fluorides Are

Useful Aspects: Dental conveys, Medical Applications, Essential Element, Glass and Ceramic, Industries, Fertilizer Industries Anti-cariogenic specialist.

Harmful Effects: Skeletal Fluorosis, Dental Fluorosis, Cardiovascular Effects, Gastro-Intestinal turmoil, Endocrine Effects Neurological Effects, Reproductive Effects, Developmental Effects, Enzyme inhabitation, Genetic damage, Effect on the pineal organ[6,7].

III. Application

The water after de-fluorination can be utilized at the domestic level.Safe drinking water with fluoride content inside allowable restrictions of 1.5 mg/L can be used for homegrown and public use. Maintaining fluoride within the limits of 1 mg/l can hinder particularly skeletal and dental issues. Ease of activity and high efficiency for fluoride evacuation and can eliminate up to 90% fluoride. Produce top-notch water.[11]

IV. Methods for Removal of Fluoride Ions from Waster Water

Different industrial processes, such as steel creation, glass fabrication, electroplating, phosphatic manure creation, clay industry, coal burning, and so on, significantly contributed to increasing the fluoride level in water.[4] Average fluoride for aluminum contraction plants accounts for 107-145 mg/L in wastewater streams. Convergences of a significant degree more noteworthy have been accounted for glass fabricating, going from 1000 to 3000 mg/L of fluoride. Henceforth, it is crucial to cut down the fluoride fixation inside the permissible range of 1.5 mg/L.[12] To vanish the dangerous effect of fluorosis, various methodologies for de- fluoridations exist.[13] Some of these are adsorption/bio-sorption, precipitation, electro- dialysis, particle trade, etc., strategies created to eliminate fluoride from water.[14]

Adsorption: Adsorption is the method of joining the particles, molecules, liquids, gas, or separate solids onto a surface, thereby setting up a film on the adsorbate. Like surface tension, adsorption is a result of surface energy and is a surface interaction.[15]

Bio-sorption: Bio-sorption is a future innovation that utilizes organic materials, for example, living microbial cells and, dead biomass to eliminate contaminations from the arrangement. In this cycle, substantial metals get accumulated on the outside of the natural materials through metabolically intervened or physico-synthetic pathways of take-up.[16] Different merits of bio-sorption over physical-synthetic procedures incorporate ease, high proficiency, minimization of substance (chemical), no additional supplement requirement, probability of recovery of bio-sorbent.[17]

Precipitation: Precipitation is a procedure of eliminating at least one substance from a mixture by adding reagents so insoluble solids become visible. The 'dissolvability' controls the process. It is one of the basic strategies to sanitize water. The synthetic compounds are added to form particles that settle and eliminate toxins from water. Precipitation is one of the simple techniques to filter polluted water. The treated water is reused, while the settled segment is dried and discarded.

Electro-dialysis: Electro Dialysis (ED) is a Membrane-based cycle during which particles are traveled through a semi-penetrable layer affected by an electric potential. The essential norm of the layer resembles the ion exchange process.

Ion exchange: The columbic attractive force among ions and charged particles are commonly named as particle trade. It is an ordinary reversible synthetic reaction where a molecule from a blend is exchanged for a nearly energized molecule hook up to a fixed solid particle.[5]

V. Tamarindus Indica

Tamarinds indicia (Tamarind) is a drought-liberal plant that is thought to have remedial properties. The abundance and availability of agricultural results make them great wellsprings of rough materials for regular sorbents.[18] The tamarind-based organic product comprises principally of mash and seeds. It is one of the most common plant of the Indian subcontinent. The tamarind tree produces earthy colored, unit-like organic products that contain a sweet-tart mash, which is utilized in cooking foods around the globe. The mash is likewise used in conventional medication and as a metal clean. The tree's wood can be used for carpentry, and tamarind seed oil can be extricated from the seeds.[19] They have no prosperity risk (wellbeing peril), and they are bio-degradable.[20]

Phytochemical examination completed on Tamarindus indica uncovered the presence of numerous dynamic constituents, for example, phenolic mixes, heart glycosides, malic acid, tartaric corrosive, adhesive, and gelatin, arabinose, xylose, galactose, glucose, and uronic corrosive. The ethanolic concentrate of Tamarindus indica demonstrated the presence of unsaturated fats and different essential components like arsenic, calcium, cadmium, copper, iron, sodium, manganese, magnesium, potassium, phosphorus, lead, and zinc.[21]

Commercial adsorbents: Various materials have been widely examined as adsorbents in water contamination control. A portion of the significant ones incorporates silica gel, enacted alumina, zeolites, and actuated carbon.

Agricultural derbies as adsorbents

- Adsorbents from rice and wheat trash.
- Adsorbents from tea and espresso trash.
- Adsorbents from coconut squander.
- Adsorbents from nut or groundnut trash.
- Adsorbents from strips of various agrarian trash.
- Adsorbents from shells of various agrarian trash.
- Adsorbents from seed, seed coat, stem, and tail of various horticultural items.[22]

Although the bio-sorbents improve the surface properties and adsorption limit by chemical and a temperature change of the bio-sorbents. In spite of synthetically modified plant debris can upgrade the adsorption of heavy metal particles, the expense of synthetic compounds utilized and techniques for alteration must be mulled over to create ‘low-cost’ adsorbents.[14]

Table 2: Comparison of bio-sorption capacities of various adsorbents for fluoride removal

Sr.No.	*Adsorbent*	*Bio-sorption capacity (mg/g)*
1.	Charcoal	7.88×10^{-5}
2.	Red mud	6.28×10^{-3}
3.	Nano-alumina	14.0
4.	Waste mud	27.2
5.	Pleurotus ostreatus (gilled mushrooms)	1.27
6.	Calcium supported carbon	19.05
7.	Alumina cement granules	10.214
8.	Granular ceramic	12.12
9.	TNFC (Virgin)	4.14
10.	TNFC (Treated)	6.11

VI. Actual Parameters Impacting Bio-sorption

To a great extent, bio-sorption relies upon parameters, such as pH, the initial metal particle concentration, bio-sorbent dosage, contact time, size of bio-sorbents, and temperature.

Impact of pH: The expulsion of fluoride particles from watery fluoride arrangement was exceptionally reliant on the arrangement pH.[23] The expansion in the pH value diminishes fluoride’s sorption as the deprotonation of the sorbent starts. These outcomes diminish the electrostatic power of fascination between the sorbent and sorbate particles. A sharp decline in fluoride expulsion might be because of the weakly ionized HF arrangement at low pH values and because of the intensity of the OH^- and F^- particles in bulk at high pH values.[24]

Impact of Temperature: The temperature also impacts the bio-sorption of metal particles, yet partially under a specific scope of temperature, which shows that the ion exchange system exists in bio-sorption to some extent. Adsorption responses are typically exothermic, so the bio-sorption limit increases with a temperature decrease.[16]

Impact of Adsorbent Dose: With expanding adsorbent dosage, more surface region is accessible for adsorption because of an increment in the binding sites, thus increasing the metal particle expulsion rate from the solution. An increase in the adsorbent dosage diminishes the adsorption limit because of the obstruction between the binding sites and the lack of metal particles in the solution due to available binding sites.[25]

Impact of Initial Fluoride Ion Concentration: When the concentration of adsorbate is low, the proportion of surface-active locations is high compared to total fluoride. Accordingly, the fluoride particles could cooperate with the sorbent to occupy binding destinations on the carbon surface sufficiently.[26] With an increment in the metal particle concentration, the adsorption limit increases, and after achieving a definite value, it becomes saturated.[25]

Impact of Contact Time: As contact time increases, anion evacuation also increases first; however, it then continuously moves toward a pretty much consistent value, signifying fulfillment of equilibrium.[25]

Impact of Adsorbent Particle Size: The shorter particles of adsorbent have bigger surface territories and give more bio-sorption locations to the metal particles, which results in an expanded adsorption limit. At higher metal particle concentration, the adsorption limit significantly relies upon molecule size because, at higher concentration, an ever- increasing number of restricting sites would be involved by metal particles. In this manner, the particles with higher surface regions, for example, shorter molecule size, would have a higher adsorption limit.[27]

Adsorption Kinetics and Adsorption Equilibrium: The energy of metal particle adsorption was assessed using two basic models: the pseudo-first-order kinetic model and the pseudo- second-order kinetic model.[28] Energy investigations of adsorption help to comprehend the evacuation rate, the system of adsorption. The Pseudo-first order and pseudo-second-order kinetic models are the most comfortable energy models for depicting any adsorption response.[27] The parameters, which are useful for the adsorption rate forecast, give significant data for planning and demonstrating the adsorption measures.[28]

VII. Conclusion

The world is confronting a furious water future. With the developing economy and rising people, the subject of all nations is 'Extra water.' The sum and nature of water ought to be given comparable importance. Care related to 'water preservation' and 'safe drinking water is critical and ought to be given a decent plan to the people. From above discussion we concluded that there are several methods which can be utilized in expulsion of heavy metals from the industrial waste waster. As Untreated Material (Tamarind Plant) is easily available at a cheaper price, thus is a financially savvy measure. It was also concluded that the bio- sorption process is the the most effective one from all the above discussed processes, it showed the maximum expulsion rate and require no additional chemical like other physico-synthetic pathways of take-up.

VIII. Future Scope

Different plants are known to have restorative impact in fluoride poisonousness yet a lot more are to find. Additionally the leaf and seeds could be additionally described utilizing Fourier Transform Infra-Red (FTIR) Spectroscopy and Gas Chromatography Mass Spectroscopy (GCMS) to clarify the jobs of tiny particles.

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2

Application of FRP Laminates in Reinforced Concrete T-Beam Bridges

Vishnu Vardhan Vallepu

Professor, HoD, MIE, LMISTE, IAENG
Siddhartha Institute of Technology and Sciences (Autonomous)
Department of Civil Engineering

ABSTRACT

This Paper describes the application of fiber-reinforced polymer (FRP) composite laminates in reinforcing an old reinforced concrete T-girder bridge in South Troy, Rensselaer County, NY. Water leaks from the ends of individual structures cause significant moisture and salt seepage into the bridge superstructure. The presence of electro-optical phenomena was observed and freeze-thaw cracking and separation of rock layers were noted in some parts of the beams. Concerns have been raised about the integrity and overall safety of the bridge's support system. These concerns are overcome by the lack of knowledge about bridge design such as rebar size, steel type, concrete strength and design loads. Therefore, it was decided to use composite FRP laminates to support the bridge. To evaluate the effectiveness of the reinforcement and to examine its effect on the behavior of the structure, a load test is performed and the test results are compared with those obtained by classical analysis.

Keywords: Advanced composites; FRP materials; Bridge rehabilitation; Bridge repair; T-beam bridges; Bridge strengthening; Innovative materials.

1. Introduction

Despite limited resources, transport agencies face continuing challenges in keeping bridges in good working order. Bridge systems are rapidly aging with repair and replacement costs.[1] Despite the availability of resources, implementation of the necessary treatment often takes a long time, disrupting traffic and inconveniencing pedestrians. Faced with these problems, transportation organizations will find solutions using fiber-reinforced polymer (FRP) for bridge repair. Although these materials have only recently entered civil engineering applications, their use is likely to increase in the coming years due to their reasonable properties and ease of assembly. Bridging with these materials is often cheaper than replacing the product and better for advertising lower prices. Use of FRP materials reduces repair times This reduces public inconvenience and economic loss in the service area. Composites have also been useful in the development of bridge measures by directly rehabilitating damaged products or indirectly replacing existing concrete with lightweight fiberglass composite decks. Epoxy resins were occasionally used in the construction of steel plates for stress points in building and bridge members in the early 1960s. However, since corrosion of steel can lead to loss of adhesion and subsequent damage, the focus has been on composite materials as an alternative. FRP panels made of glass (GFRP), aramid (AFRP) and carbon (CFRP) fibers embedded in polymer resins are now replacing steel plates.

Besides being corrosion resistant, composites are stronger and lighter than steel. Section examined the behavior of reinforced crack by bonding FRP (glass, carbon and aramid) sheets to the stress zone and showed that FRP increased beam stiffness by 17-79%, while beam boundary strength increased by 40-40%. 97%. O'Connor et al. Economic efficiency and results of beams using composite FRP laminates:

2. Background and Objectives

The simple span reinforced concrete T-beam structure was built in 1932 with a solid slab. The bridge is 12.19 meters long and approximately 36.58 meters wide and is supported by a total of 26 columns 1.37 meters apart. Space center. The plan view of the bridge and the cross section of the bridge deck are shown in Figure 1. Since then, the bridge has been reopened to traffic with an average daily traffic of 30,000 vehicles. This five-lane road is the main road connecting the city of South Troy to the western part of the Hudson River. During the routine inspection, it was determined that excessive moisture and salt leakage occurred in the bridge superstructure. Large-scale electro-photochemical and freeze-thaw cracks were seen in many beams, and several beams showed signs of rock delamination. Concerns about section loss and overall safety of the structure due to rebar corrosion are only exacerbated by the lack of information that includes all the information needed to assess the reliability of the structure. The New York Department of Transportation (NYSDOT) chose to repair the structure rather than replace or install it. Fiberglass laminate reinforcement system has been chosen for its application that has the least impact on traffic and provides the best performance. The renovation was completed between August and November 1999 and includes a full platform assembly, surface preparation and laminate installation under the bridge. The purpose of the research discussed in this paper is to evaluate the effectiveness of the FRP effort used in the project and to investigate its effect on the behavior of the bridge using the "before" and "after" load measurement results. 'Development of laminate systems.

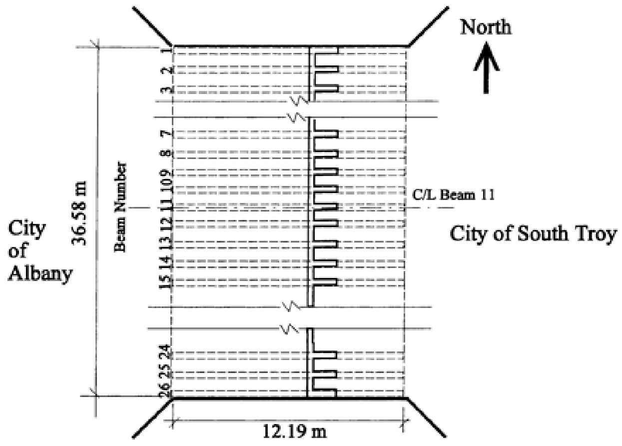


Fig. 1: Bridge plan and transverse section

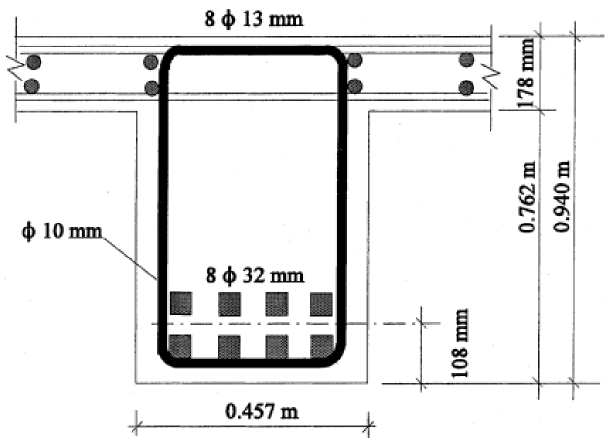


Fig. 2: Bridge plan and transverse section

Table 1
Summary of service load stresses

Design load (MPa)	M18	MS18	Allowable stress (MPa)
Steel-rebar stress	85.63	97.15	113.76
Concrete stress	4.21	4.76	8.27

3. FRP-Laminate System Design and Installation

The design, finishing and laminate installation of the supporting equipment will be discussed in the next section. The design of the laminate is prepared by a third party under contract with the laminate manufacturer. The design is part of the warranty agreement between the department and the manufacturer regarding the overall performance of the system. Follow the manufacturer's recommended procedures for surface preparation and laminate installation.

Flexural and shear design of the system were based on an assumed 15% loss, due to corrosion, of the steel-rebar area. According to this approach, required area of laminates Al was calculated based on the following equation:

$$A_l = 0.15(A_sF_y)/F_l, \tag{1}$$

where As and Fy are, respectively, area and yield stress of steel-rebars, and Fl is the design stress of the laminate material. It is important to note that this approach does not account for strain compatibility and was used for simplicity. A more realistic approach to size the laminates, under the same premise of compensating for steel rebar area lost to corrosion, would require the laminate area Al be based on

$$A_l = 0.15(d - \beta_1 c/2)A_sF_y/[(h - \beta_1 c/2)F_l], \tag{2}$$

where d is the beam effective depth, β1c is the depth of the Whitney equivalent rectangular stress block, and h is the beam total depth. The webs were strengthened for shear using U-jackets to contain further propagation of the delamination and freeze-thaw cracking and provide additional anchorage for the main laminates. The design of these jackets was also based on a similar percentage-loss of the shear reinforcing-stirrups. However, this approach is also not precise and the method for estimating laminates contribution to shear strength described in would be more appropriate. The laminate system assumed in the design (Fig. 3) was Replark System®, consisting of Replark 30® unidirectional carbon fibers and three types of Epotherm materials, primer, putty, and resin, all manufactured exclusively by Mitsubishi Chemical Corporation of Japan.[27] Properties of the Replark 30® laminates are summarized in Table 2. The ultimate strength of 3400 MPa, corresponds to a guaranteed ultimate strain of 1.5%. Design strength is specified as 2/3 the ultimate strength. Unlike most materials, the stress strain curve for FRP-laminates generally exhibits elastic (linear) behavior until failure is reached. In Fig. 3, laminates located at the bottom of the beams webs and those between beams, indicated as full span length, are oriented parallel to the beams. Those at the flange soffits, spanning between beams, are oriented in a direction at a right angle to the beams. The U-jacket laminates, applied on the bottom and sides of the beams, are oriented parallel to the legs of the U-jackets.

3.1 Installation of the FRP-Laminate System

Surface preparation and laminate installation were performed according to the procedures recommended by the laminate manufacturer.[27] First, areas of the beams

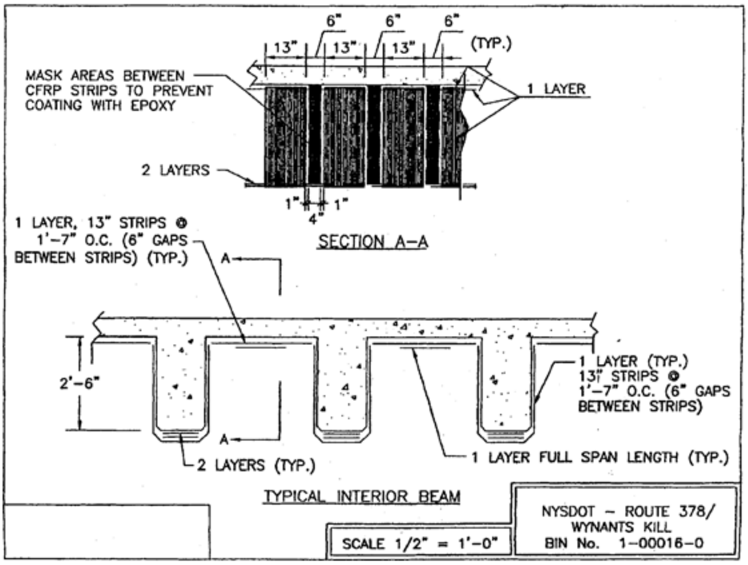
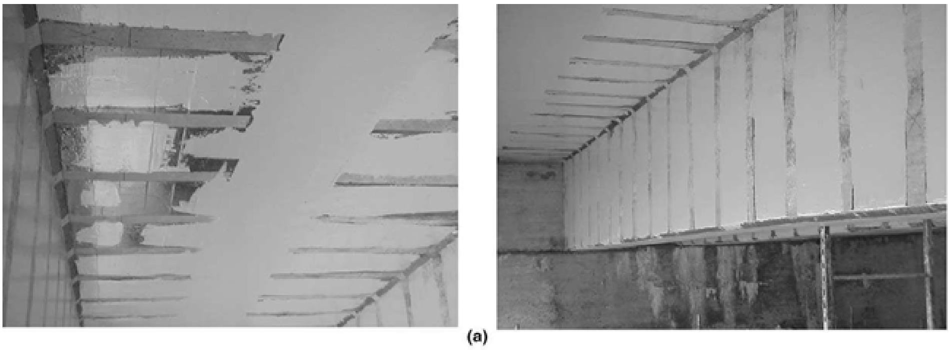


Fig. 3: Proposed strengthening FRP-laminate system



(a)

(b)

Fig. 4: (a) Primer and putty applied at marked locations. (b) Installed FRP-laminate system in place (painted to match concrete color)

with visible cracking were repaired (by removing loose concrete and replacing it with new patching concrete, and filling the cracks with a cement-based grout material) and those with uneven surfaces were grinded to a smooth finish. Sharp edges around beam webs were smoothed. Then the bridge underneath was sand-blasted and pressure washed with water to remove any loose surface materials that could lead to debonding of the laminates. After the surface was dry, laminate locations were clearly marked. A primer was applied followed by a putty at the locations where the FRP laminates were to be installed (Fig. 4(a)). An epoxy resin was applied to the surface, followed by placement of the laminates. Roller pressure was applied to impregnate the laminate as per manufacturer's specifications[27] and heaters were used to control curing temperature. Properties of the primer, putty, and resin are given in Section 1.2 of Ref.[27] Finally, the FRP laminates were painted for protection from ultraviolet light and for aesthetics reasons (Fig. 4(b)). The ''after'' load test was conducted 10 days after installation; the manufacturer recommended a 7-day minimum cure time.

4. Load-test and Instrumentation Plans

The main objectives of the testing program were to evaluate, through ''before'' and ''after'' installation load testing, effectiveness of the laminate system in reducing live-load stresses in the bridge beams and deck, and to provide information for investigation of the system's effect on bridge behavior. Instrumenting only nine beams out of 26, when two lanes centered directly above the beams are loaded, was judged to be adequate to reflect transverse live-load distribution. These are labeled Beams 7–15 in Fig. 1. For flexural evaluation only, steel-rebars and laminate strains were acquired at the midspan of these beams to provide information on liveload distribution. Two other locations on the center beam were also instrumented: near the support to investigate the effect of the strengthening system on shear, and at quarter and midspan to assess laminate bond to concrete and laminate stresses. Locations of the instrumentation used to measure these strains on the steel rebars, concrete, and laminates are shown in Figs. 5–7, respectively. Based on this plan, steel-reinforcement and laminate stresses, as well as effective flange width and position of the neutral axis on the center beam can be determined. Additionally, concrete shear stresses at one end of the center beam can also be determined constantan strain gages with large measuring grids were bonded using an epoxy resin. In all, 10 strain gages were mounted on steel rebars, 13 on concrete in the ''before'' installation test, and an additional 18 were bonded to laminates for the ''after'' installation test (Figs. 5–7). All gages used in both tests were made watertight and protected from the environment for long-term monitoring

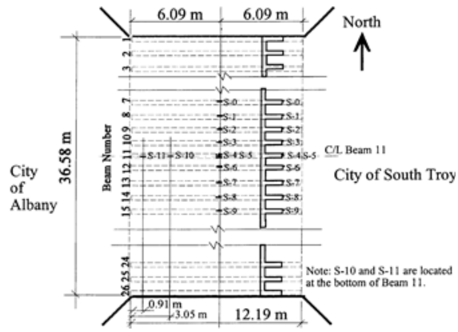


Fig. 5: Locations of strain-gages mounted on steelbars

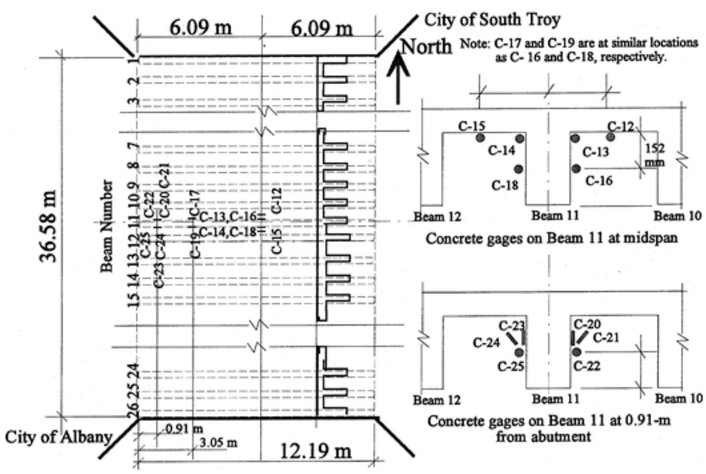


Fig. 6: Locations of strain-gages mounted on concrete

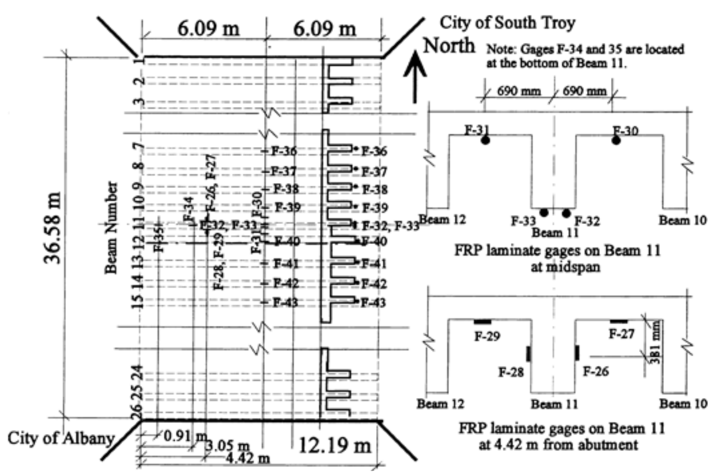


Fig. 7: Locations of strain-gages mounted on FRP laminates

purposes. System 4000, a general purpose strain gage measurement system, also manufactured by the Measurements Group®, was used for data acquisition.

5. Load-test Trucks

Four trucks, each of the typical configuration shown in Fig. 8, were used in the load tests. Average weight of each of these trucks is approximately 196 kN. By assigning a unique letter, A–D, to each of the four trucks truck combinations at 3.66, 4.11 and 4.42-m positions on the bridge are shown in Fig. 10. These results clearly confirm adequacy of the test plan to instrument nine beams and show Beam 11 to be the most stressed beam, as planned.

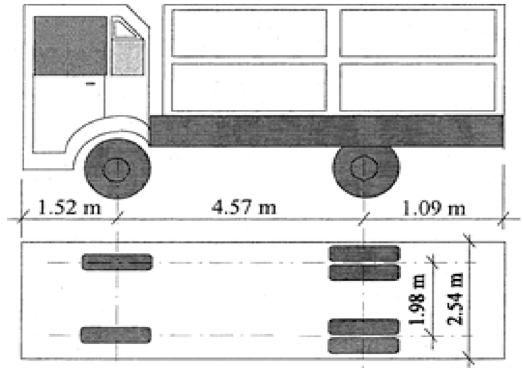


Fig. 8: Load-test truck configuration

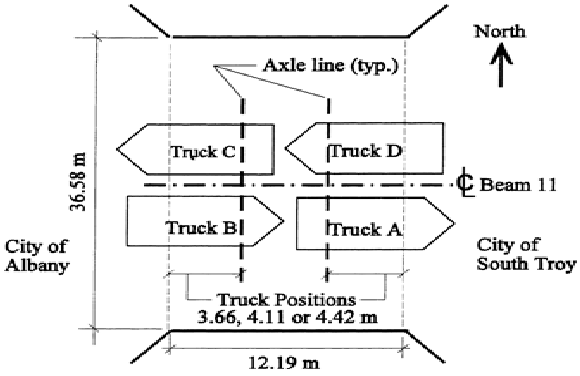


Fig. 9: Truck positions for the "before" and "after" installation load tests

"Before" and "after" installation strains for gages mounted on steel-rebars and concrete for all four trucks (Trucks A + B + C + D) at 4.42-m position on the bridge are shown in Fig. 11. Similar results for the "after" installation strains for gages mounted on the laminates are shown in Fig. 12. Comparing the "before" and “after” readings for gages mounted on the steel rebars (Fig. 11), it can be concluded that installation of the FRP laminates slightly reduced rebar stresses. Relatively higher “after” than “before” installation rebar strains in this figure may be attributed to noise in readings and minor changes in truck positions during the testing. Also from these figures, Gage S-11 which is located 0.914-m from the Albany side abutment at the bottom of Beam 11 consistently measured negative readings (compressive strains), indicating end fixity of the beam which was verified through back-calculation of moments based on measured strains. Freezing of the expansion bearings is the most likely cause of this fixity, which substantially reduced midspan live-load moments. For example, Beam 11 moment with all four trucks positioned at 4.42 m from the abutments was reduced from 209.10 (based on simply supported conditions) to 75.93 kN m. This may be compared to 79.72 kN m calculated based on recorded strains. Comparing the FRP strains in Fig. 12 with those recorded on the rebars (Fig. 11), it can be concluded that laminate strains for

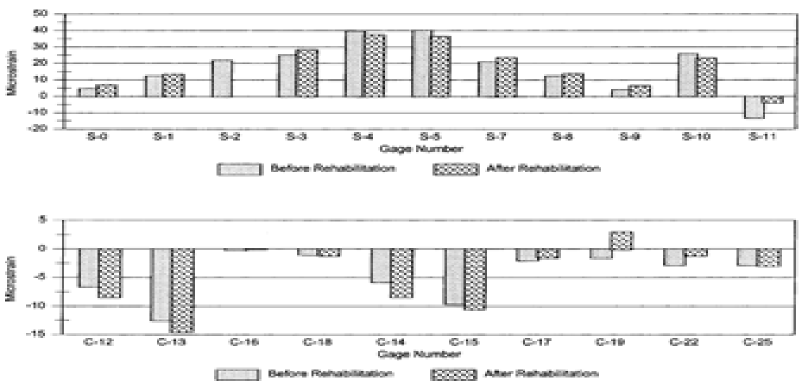


Fig. 10: Recorded strains in the “before” and “after” tests for gages mounted on steel bars and concrete. (All four trucks parked at 4.42-m position.)

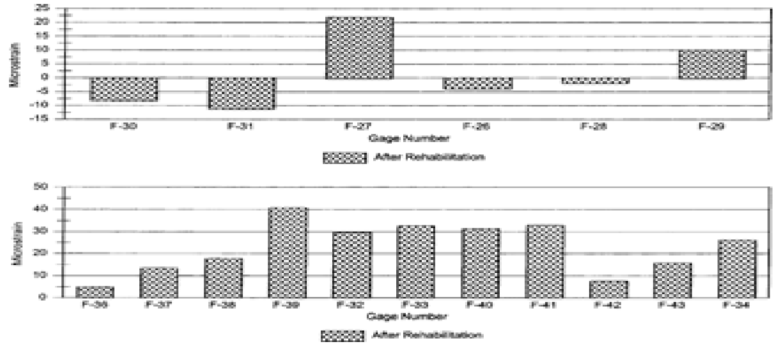


Fig. 11: Recorded strains in the “after” tests for gages mounted on FRP laminates. (All four trucks parked at 4.42-m position on the bridge.)

some gages were lower than expected. Since the laminates are physically located below the main rebars in the beam section, strain compatibility requires laminate strains to be higher than rebar strains.

6. Conclusions

Application of FRP laminates to contain freeze-thaw cracking and improve flexural and shear strength of a reinforced-concrete T-beam bridge structure was discussed in this paper. Load tests were conducted before and after installation of the laminates to evaluate effectiveness of the strengthening system. Tests results were analyzed and compared with those obtained using classical analysis. Load tests results revealed that, after installation of the laminates, main rebar stresses were moderately reduced, concrete stresses (flexural and shear) moderately increased, and transverse live-load distribution to the beams slightly improved under service loads. Although the laminates participated in load carrying, compatibility of strains was not satisfied at some locations, possibly caused by lack of full-bond development at the time of the testing of the level of precision in strain measurements. Unintended fixity of the beams ends, which substantially reduced expected moment and shear, was discovered. As expected, location of the neutral axis was observed to have migrated down after the laminates were installed, and effective flange width remained almost unchanged for all truck positions. The benefits of the FRP-laminate system used in this Project may not be fully realized within the loading range used in the testing program. However, various studies have concluded significant increase in ultimate capacities of concrete members strengthened using these laminates. The maximum load applied during the testing program, about 2.75 MS18 loading, was not sufficient to induce nonlinear behavior. Feasibility of using laminates for bridge strengthening in this project, with minimal interruption to traffic, should encourage their use in similar applications in highly populated metropolitan areas.

Using bonded FRP laminates in this project provided an opportunity for NYSDOT to demonstrate their use and investigate their feasibility as a cost-effective bridge rehabilitation technique. Total cost of the rehabilitation is estimated at \$300,000, which may be compared to \$1.2 million required for replacement of the structure.

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3

Structural Elucidation of Drug 1-Hydroxyurea (Hydrea) by Using Argus Lab 4.0.1 Software

K. Laxmi

Department of Chemistry, Chaitanya Bharathi Institute of Technology (CBIT), Gandipet, Hyderabad, India.

*Corresponding author E-mail: klaxmi_chm@cbit.ac.in

ABSTRACT

1-Hydroxyurea (Hydrea) is an antineoplastic (anti-cancer) agent. With the help of ArgusLab 4.0.1 software according to the Hartree-Fock (HF) calculation method Conformational analysis and geometry optimization of 1-Hydroxyurea (Hydrea) was performed. Calculation of minimum heat of formation of 1-Hydroxyurea (Hydrea) is done by geometry convergence function applying Argus Lab software. In order to obtain geometries, geometric parameters and thermodynamic parameters PM3 semi empirical quantum mechanical calculations were performed on the most stable structure of 1-Hydroxyurea (Hydrea). Applying the optimized molecule HOMO and LUMO frontier orbital energies were also determined. Electron density surface of 1-Hydroxyurea (Hydrea) is estimated by employing PM3 geometry with PM3 wave funciton.

Keywords: 1-Hydroxyurea, ArgusLab 4.0.1, PM3 semi empirical quantum mechanical calculations, conformational analysis, geometry optimization, HOMO and LUMO, Electron density surface.

Introduction

Hydroxyurea belongs to a class of drugs called antimetabolites.[1,2] In order to treat chronic myeloid leukemia, ovarian cancer, and certain types of skin cancer (squamous cell cancer of the head and neck) Hydroxyurea is used.[3,4] When hydroxyurea is administered in people suffering with Cancer it acts as a substitute for some parts that the cancer cells need to grow. As a result when Cancer cells take in hydroxyurea, it prevents the cancer cell from growing.[5-7] Because Cancer cells grow more rapidly than normal cells, the drug hydroxyurea is more effective.

Materials and Methods

In an effort of minimization and representations of molecular structure and for construction of models many tools have been generated by Computational advances.[8-11] Applying Argus lab software all conformational analysis (geometry optimization) study was executed on a window based computer. Applying semi-empirical Parametric Method 3 (PM3) parameterization[12,13] the structure of hydroxyurea is developed by Argus lab, and minimization was achieved. In Argus lab software by operating geometry convergence function the minimum potential energy is calculated. Aiming to visualize ground state properties as well as excited state properties surfaces were created and data is generated. Applying the geometry convergence map[14,15] the minimum potential energy for Hydroxyurea was calculated. Executing PM3 method Mulliken Atomic Charges, ZDO Atomic Charges of IDOX and Ground State Dipole (debye) of hydroxyurea were determined.

Results and Discussions

The molecule 1-Hydroxyurea (Hydrea) is build using molecule builder of Argus lab. Using Argus lab software[16-18] all conformational analysis (geometry optimization) study of 1-Hydroxyurea was executed on a window based computer. I3C structure is of 1-Hydroxyurea is designed and by applying the semi-empirical Parametric Method 3 (PM3) parameterization. minimization was performed.

Hypothetical Study of 1-Hydroxyurea (Hydrea) by Argus Lab Software

Using molecule builder of Argus lab. The molecule 1-Hydroxyurea is build and its Molecule Settings are Atoms 9, Net charge 0 and Valence electrons 30. Prospective view and various display forms of active conformation of 1-Hydroxyurea are shown in Figs. 1 and 2.

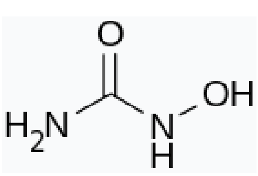

Fig. 1: Structure of 1-Hydroxyurea (Hydrea)

The atomic input information for above calculation is given in Table 1. The final geometrical energy and SCF energy of 1-Hydroxyurea was found to be -45.3610208818 au/-28464.4960 kcal/mol as calculated by RHF/PM3 method, as performed by Argus Lab 4.0.1 suite (Table 2).

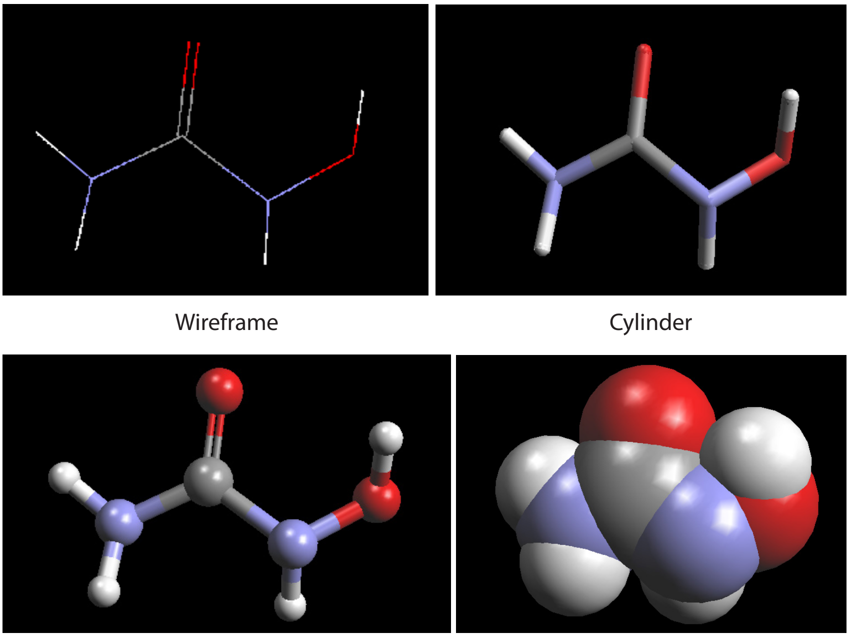

Fig. 2: Perspective view of active conformation of 1-Hydroxyurea (Hydrea) as optimized by ArgusLab 4.0.1 software in various forms

Table 1: Atomic coordinates of 1-Hydroxyurea (Hydrea) - Input Atomic Information				
1	N	–0.6652	–0.29866	–0.21256
2	C	0.372292	0.753457	–0.2736
3	O	0.286577	1.540456	0.745486
4	N	1.713339	0.144011	–0.32464
5	O	2.513109	1.117269	–0.78737
6	H	–1.56287	0.270117	–0.13557
7	H	–0.59704	–0.6533	0.790911
8	H	1.626054	–0.4796	–1.18355
9	H	2.816246	1.870297	–0.18404

Table 2: Calculating SCF using one electron matrix—Performing SCF					
Cycle	*Energy (au)*	*Difference*	*Cycle*	*Energy (au)*	*Difference*
1	–36.852713		25	–45.3610208	–4.17E–08
2	–39.25145989	–2.39875	26	–45.3610209	–2.34E–08
3	–40.68158656	–1.43013	27	–45.3610209	–1.38E–08
4	–42.58357431	–1.90199	28	–45.3610209	–7.78E–09

Contd…

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Cycle	*Energy (au)*	*Difference*	*Cycle*	*Energy (au)*	*Difference*
5	–44.01615916	–1.43258	29	–45.3610209	–4.43E–09
6	–45.03796124	–1.0218	30	–45.3610209	–2.53E–09
7	–45.29067057	–0.252709	31	–45.3610209	–1.44E–09
8	–45.34680987	–0.0561393	32	–45.3610209	–8.22E–10
9	–45.35899689	–0.012187	33	–45.3610209	–4.68E–10
10	–45.3604394	–0.00144251	34	–45.3610209	–2.67E–10
11	–45.36077492	–0.000335521	35	–45.3610209	–1.52E–10
12	–45.36090658	–0.000131659	36	–45.3610209	–8.69E–11
13	–45.36096383	–5.72E–05	37	–45.3610209	–4.93E–11
14	–45.36099085	–2.70E–05	38	–45.3610209	–2.82E–11
15	–45.36100456	–1.37E–05	39	–45.3610209	–1.62E–11
16	–45.36101184	–7.28E–06	40	–45.3610209	–9.21E–12
17	–45.36101581	–3.98E–06	41	–45.3610209	–5.09E–12
18	–45.36101802	–2.21E–06	42	–45.3610209	–3.04E–12
19	–45.36101926	–1.24E–06	43	–45.3610209	–1.65E–12
20	–45.36101996	–7.00E–07	44	–45.3610209	–1.08E–12
21	–45.36102036	–3.94E–07	45	–45.3610209	–5.40E–13
22	–45.36102058	–2.27E–07	46	–45.3610209	–1.99E–13
23	–45.36102071	–1.29E–07	47	–45.3610209	–3.69E–13
24	–45.36102079	–7.32E–08	48	–45.3610209	2.84E–14

Final SCF Energy = –45.3610208818 au
Final SCF Energy = –28464.4960 kcal/mol

Mulliken Atomic Charges, ZDO Atomic Charges and Ground State Dipole (debye) of 1-Hydroxyurea were given in Tables 3 and 4.

Wiberg Atom-Atom Bond Orders of 1-Hydroxyurea were given in Table 5.

Table 3: List of Mulliken Atomic Charges and ZDO Atomic Charges of 1–Hydroxyurea using ArgusLab software

Numbering of atoms	*Atom*	*Mulliken Atomic Charges*	*Numbering of atoms*	*Atom*	*ZDO Atomic Charges*
1	N	–0.5648	1	N	–0.4051
2	C	0.3631	2	C	0.2889
3	O	–0.3993	3	O	–0.3754
4	N	–0.2247	4	N	–0.147
5	O	–0.2933	5	O	–0.2488

Contd...

Contd…

Numbering of atoms	*Atom*	*Mulliken Atomic Charges*	*Numbering of atoms*	*Atom*	*ZDO Atomic Charges*
6	H	0.2972	6	H	0.2323
7	H	0.2801	7	H	0.2172
8	H	0.2557	8	H	0.1957
9	H	0.2861	9	H	0.2423

Table 4: Ground State Dipole (debye) of 1-Hydroxyurea using ArgusLab software

X	*Y*	*Z*	*Length*
–1.0300702	–3.129911	0.359029	3.31455742

Table 5: Wiberg Atom-Atom Bond Orders of 1-Hydroxyurea using ArgusLab software

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
1	0								
2	1.097885	0							
3	0.138232	1.718292	0						
4	0.043109	0.956618	0.089829	0					
5	0.012398	0.029232	0.007211	1.013809	0				
6	0.908139	0.007454	0.004435	0.014957	0.00221	0			
7	0.915417	0.010036	0.017247	0.000482	0.000128	0.008832	0		
8	0.002251	0.008515	0.013712	0.922787	0.003126	0.000026	0.000694	0	
9	0.000122	0.000678	0.002974	0.000971	0.925917	0.000001	0	0.01061	0

Heat of formation: The atomic heat of formation is the heat released under standard conditions in the process of formation of stable form of the element from individual atoms. Applying Argus Lab software the heat of formation of most energetically favorable conformation of 1-Hydroxyurea is -51.5430 kcal/mol.

HOMO and LUMO Orbitals of 1-Hydroxyurea

Chemical reactivity is well explained with the help of HOMO and LUMO orbitals which are commonly known as Frontier Orbitals. Atomic sites having high density of the HOMO orbital were correlated with Electrophilic attacks and atomic sites having high density of the LUMO orbital were correlated with nucleophilic attacks. This concept was first developed by Scientist Kunichi Fukui for which he was awarded the Nobel prize in chemistry in 1981.

HOMO (Highest Occupied Molecular Orbital i.e MO 15)and LUMO (Lowest Unoccupied Molecular Orbital i.e MO 16) of 1-Hydroxyurea are shown in fig.3

and fig.4 respectively. This was done theoretically using PM3. The calculated Eigen values and eigen vectors of HOMO (MO 15)and LUMO(MO 16) are given in Tables 6 & 7.

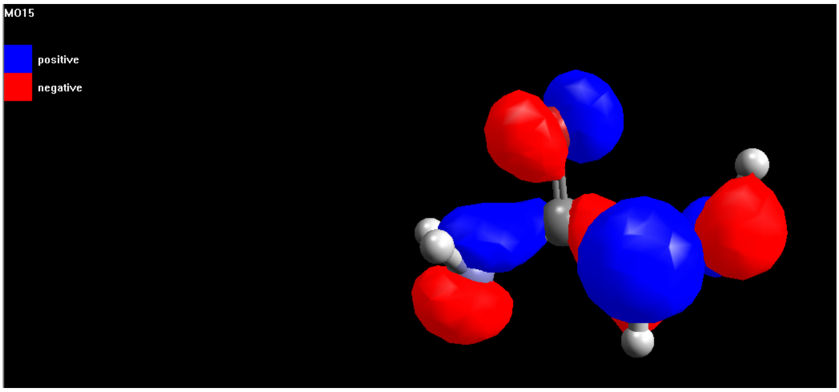

Fig. 3: Visualize the HOMO (Highest Occupied Molecular Orbitals) (MO 15) of 1-Hydroxyurea, blue shows positive and red shows negative.

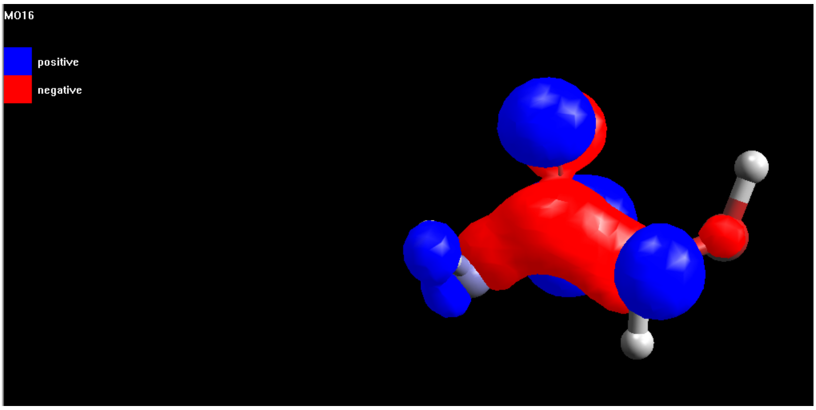

Fig. 4: Visualize the LUMO (Lowest Unoccupied Molecular Orbitals) (MO 16) of 1-Hydroxyurea, blue shows positive and red shows negative

Table 6: Data of eigen values and Eigen vectors of HOMO (MO 15) of 1-Hydroxyurea MO Number 15 Eigen values(au) -0.380697

		eigenvectors			*eigenvectors*
1	N 2S	0.033435	4	N 2S	0.253033
1	N 2Px	0.111566	4	N2Px	0.32851
1	N 2Py	0.074328	4	N2Py	–0.231036
1	N 2Pz	0.097698	4	N2Pz	0.60371
2	C 2S	–0.06756	5	O 2S	0.037153
2	C 2Px	–0.134864	5	O2Px	–0.191737

Contd...

Contd…

		eigenvectors			***eigenvectors***
2	C 2Py	0.031314	5	O2Py	0.187146
2	C 2Pz	0.053936	5	O2Pz	–0.237484
3	O 2S	0.000615	6	H 1S	–0.039695
3	O 2Px	0.252253	7	H 1S	–0.007592
3	O 2Py	0.095631	9	H 1S	–0.080642
3	O 2Pz	–0.369886			

Table 7: Data of eigen values and Eigen vectors of LUMO (MO 16) of 1-Hydroxyurea MO Number 16 Eigen values(au) 0.024432

	eigenvectors		eigenvectors
1 N 2S	–0.100913	4 N 2S	0.217606
1 N 2Px	0.091405	4 N 2Px	0.086182
1 N 2Py	0.068911	4 N 2Py	0.031115
1 N 2Pz	0.181818	4 N 2Pz	0.030224
2 C 2S	–0.056849	5 O 2S	–0.033807
2 C 2Px	–0.185814	5 O 2Px	0.124755
2 C 2Py	0.161132	5 O 2Py	0.10143
2 C 2Pz	–0.680551	5 O 2Pz	–0.12243
3 O 2S	0.001544	6 H 1S	0.061681
3 O 2Px	0.126832	7 H 1S	0.14239
3 O 2Py	–0.100024	8 H 1S	–0.190824
3 O 2Pz	0.480482	9 H 1S	0.026248

Electronic properties: In order to explain the electronic properties of compound it is essential to examine the E HOMO and E LUMO and this is executed theoretically by applying PM3. In an orbital the positive and negative phases are denoted by the two colors with the blue regions and the red regions indicating an increase in electron density and a decrease in electron density respectively. The calculated E HOMO and E LUMO and band gap of 1-Hydroxyurea are recorded in Table 8.

Table 8: Electronic Properties of 1-Hydroxyurea

Methods	***HOMOenergy(ev)***	***LUMO energy(ev)***	***Band gaps (ev)***
PM3	–0.380697	0.024432	–0.356258

Electrostatic Potential of 1-Hydroxyurea

The electrostatic potential is a physical property of a molecule related to how a molecule is first “seen” or “felt” by another approaching species. A distribution of electric charge creates an electric potential in the surrounding space. A positive electric potential means that a positive charge will be repelled in that region of space. A negative electric potential means that a positive charge will be attracted. A portion of a molecule that has a negative electrostatic potential will be susceptible to electrophilic attack - the more negative the better. Quick Plot ESP mapped density generates an electrostatic potential map on the total electron density contour of the molecule. The electron density surface depicts locations around the molecule where the electron probability density is equal. This gives an idea of the size of the molecule and its susceptibility to electrophilic attack. Below is an electron density surface of 1-Hydroxyurea using PM3 geometry with PM3 wave function. The surface color reflects the magnitude and polarity of the electrostatic potential. Fig.5 shows the complete surface of 1-Hydroxyurea with the color map. This figure uses a clipping plane showing a cutaway of the same surface revealing the underlying molecular structure. The color map shows the ESP energy (in hartrees) for the various colors. The surface color reflects the magnitude and polarity of the electrostatic potential. The red end of the spectrum shows regions of highest stability for a positive test charge, magenta/blue show the regions of least stability for a positive test charge. These images show that the carboxyl-end of the molecule is electron rich relative to the amino end.

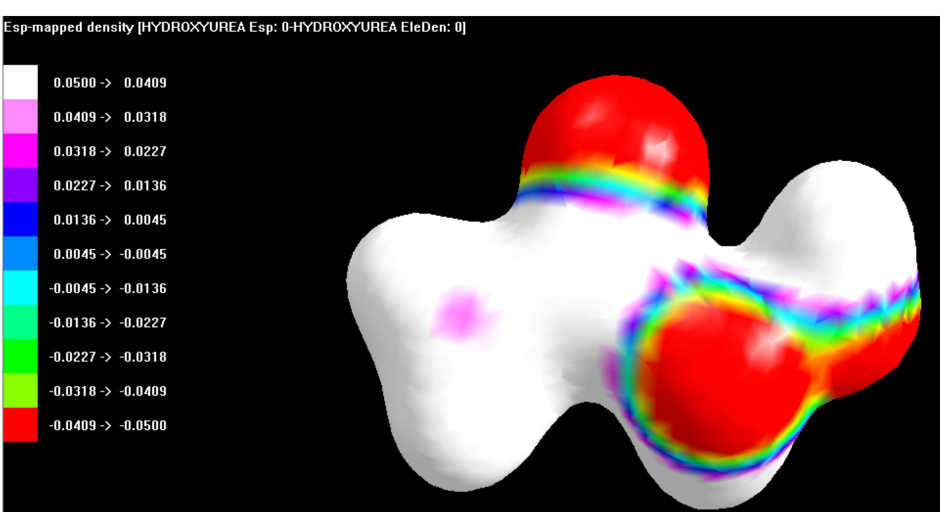

Fig. 5: ESP energy surface of 1-Hydroxyurea with the color map

	0.0500 to 0.0409		–0.0045 to –0.0136
	0.0409 to 0.0318		–0.0136 to – 0.0227
	0.0318 to 0.0227		–0.0227 to – 0.0318
	0.0227 to 0.0136		–0.0318 to –0.0409
	0.0136 to 0.0045		–0.0409 to –0.0500
	0.0045 to –0.0045		

Conclusion

The present work indicates that the optimized geometries, dipole moments, Mulliken Atomic Charges and ZDO Atomic Charges and thermodynamic parameters were calculated and the data obtained from the calculated parameters are analysed and is found to be well within the accuracy of computational results. In conclusion, the modeling and the calculations does not only presented us the opportunity to take a critical look at this novel compound 1-Hydroxyurea but has also given us the opportunity to compile fundamental results on properties that cannot be calculated in the laboratory.

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4

Combination Therapy of Medicinal Gases in the Complication of COVID-19—An Overview

[1]Lisiya S, [2]Charupriya M, [3*]R. Jasmin Sajini, [4]R. Karthik

[1-2]II. Pharm. D, Sri Ramachandra Faculty of Pharmacy, Sri Ramachandra Institute of Higher Education and Research (Deemed to be University), Porur, Chennai - 600116, Tamil Nadu, India.

[3*]Assistant Professor, Department of Pharmaceutical Chemistry, Sri Ramachandra Faculty of Pharmacy, Sri Ramachandra Institute of Higher Education and Research (Deemed to be University), Porur, Chennai - 600116, Tamil Nadu, India .e-mail id: karthikjasmin0214@gmail.com.

[4]Head-Bioanalytical & Analytical, Scitus Pharma Services Pvt Ltd, Thirumazhisai, Chennai - 600124.
e-mail id: karthikjasmin0214@gmail.com

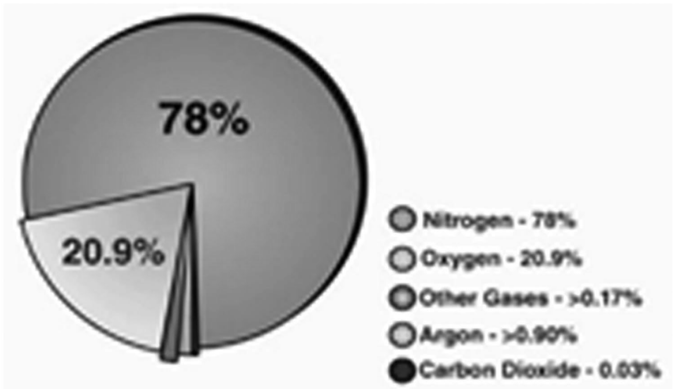
ABSTRACT

Oxygen, hydrogen, carbon monoxide, carbon dioxide, nitrogen, xenon, hydrogen sulphide, nitrous oxide, carbon disulfide, argon, helium, and other noble gases are all members of the wide family of medicinal gases. Anesthesiology, hyperbaric oxygen therapy, diving medicine, internal medicine, emergency medicine, surgery, and numerous basic science fields like physiology, pharmacology, biochemistry, microbiology, and neuroscience all use these therapeutic gases. Regrettably, not even one journal is devoted to basic, translational, or clinical medical gas research; notably in the domains of neurobiology or neurology, much alone the other diverse medical fields.so attempt to this review to highlight medicinal uses,combination of medicinal gases in therapy.

Keywords: Medical gas, anesthesia, Diagnosis.

1. Introduction

Pharmaceutical gases are made, packed, and intended to be given to a patient during anaesthesia, therapy, or diagnostic procedures. Medical gases have many applications in hospital therapy.[1] Because it is risky for a person to use medical gases without the guidance of a licenced medical practitioner, they are categorised as medicines. Respiratory therapists have access to a number of therapeutic gases.[2] Patients often receive medical gases before, during, and after surgery in addition to those who require them in an emergency. These gases must be supplied in



Picture 1: Compositional gases in the atmosphere[48]

an airtight, color-coded well-lab. A substance is defined as a gas if, when under pressure, it exclusively retains its gaseous state.[3]

Medicinal gases in large quantities, including oxygen and air are available. Respiratory therapists have a wide range of medical gases at their disposal.

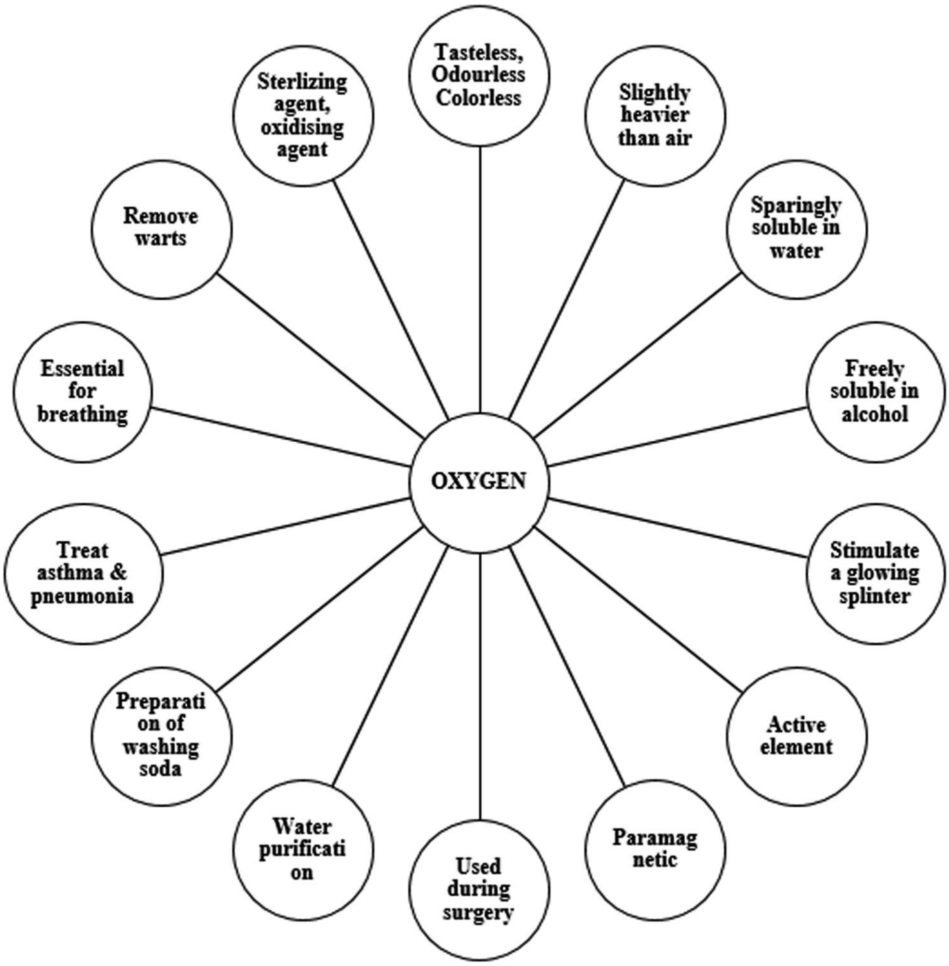
Before use, gases intended for medicinal or diagnostic reasons must pass stringent testing and adhere to criteria.Medical-grade gases are essential to the delivery of care at all stages. The respiratory therapist must be informed with the several types of gases that are utilised, as well as how they are made, delivered, and stored until they are needed. This explains the fundamentals of producing, holding, moving, and using medicinal gases in a range of healthcare situations.[4]

Compressed gases utilised in clinical procedures including symptom treatment, anaesthesia, or powering and conditioning medical apparatus or devices are how modern medical gases are typically described. Six separate gases—O_2, N_2, N_2O, Ar, He, and CO_2—as well as three gaseous mixtures—Entonox, which contains 50% N_2O and 50% O_2, Heliox, which contains 79% He and 21% O_2—are frequently used in hospitals.[8] Medical gases are thus characterised in this review as pharmacological gaseous molecules that meet the therapeutic requirements of particular pathophysiologic conditions.[5]

2. Oxygen as Medicinal Gas

Oxygen is one of the gases that is most frequently utilised for respiratory therapy and life support.[6] Oxygen is necessary for both human and animal life. It accounts for around 21% of the atmosphere and 50% of the terrestrial matter. Plants take up carbon dioxide and expel oxygen during photosynthesis.[7] Oxygen's harmful side effects include The respiratory system is the first to be damaged by an oxygen

Flowchart 1

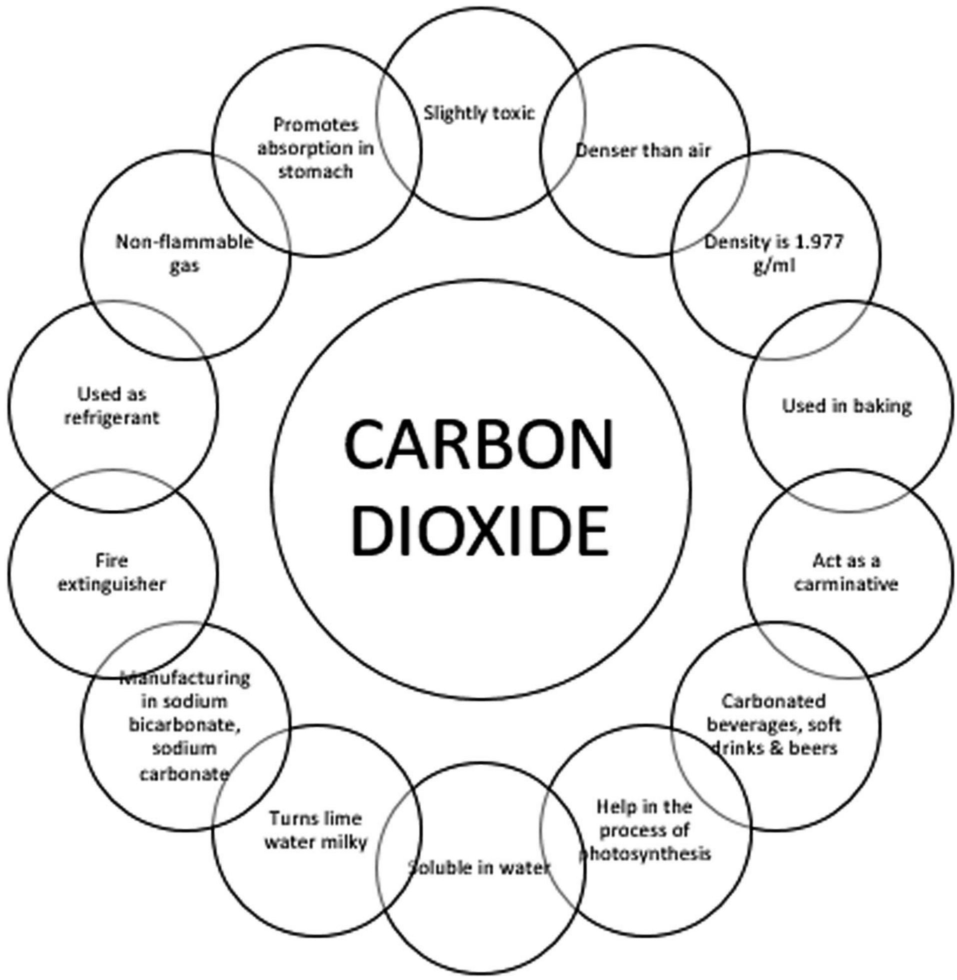


supply that is steady for longer than 15 hours. Reterolentalhyplasis can happen in kids.[8] Seizures and temporary blindness are two of the CNS symptoms that only manifest at 200 atm of oxygen partial pressure. It is safe to use during pregnancy and nursing.[9]

3. Carbon Dioxide as Medicinal Gas

About 0.03% of the atmosphere is made up of carbon dioxide. It comes about as a result of processes like fermentation, respiration, and combustion.[10] The harmful effects of CO_2 are prohibited in cases of metabolic acidosis. Above a concentration of 6%, carbon dioxide causes headaches, nausea, dizziness, disorientation,

Flowchart 2: Properties and uses of carbondioxide

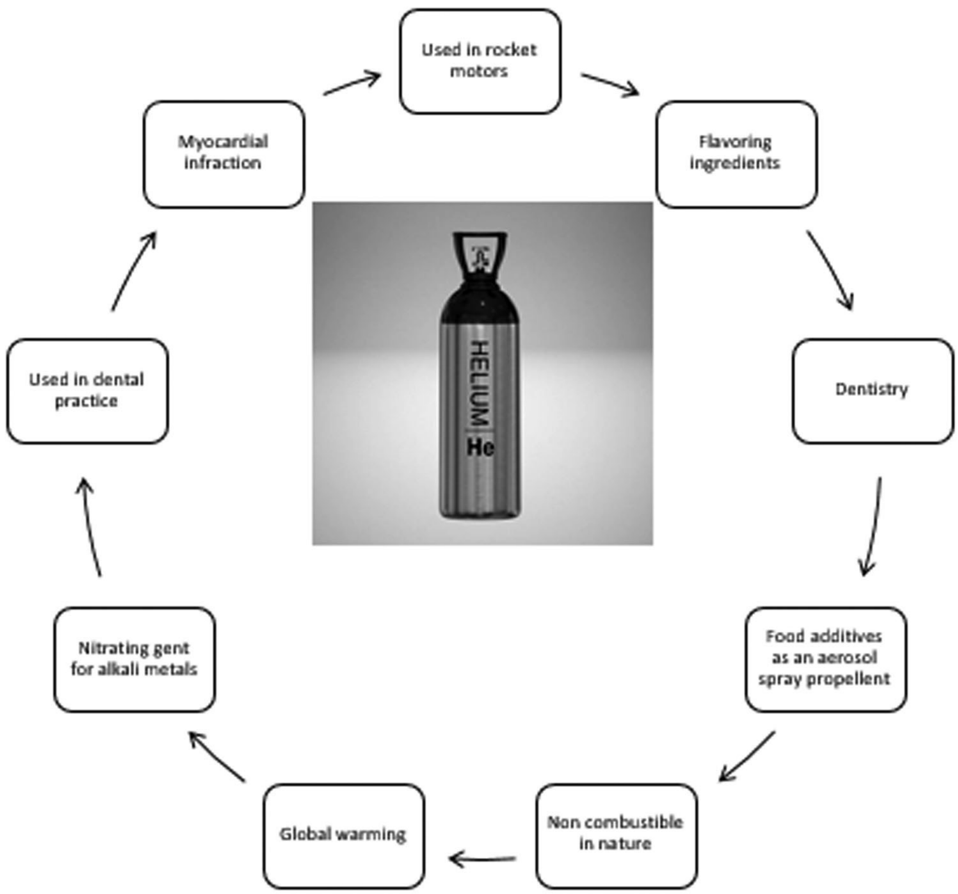


palpitations, hypertension, dyspnea, increased depth and rate of respiration, and CNS depression.[7,8,10] At concentrations of 20% and higher, convulsions and loss of consciousness occur, and breathing in 50% carbon dioxide is claimed to have similar central effects as anesthetics.[11]

4. Helium as Medicinal Gas

Helium is an inert gas that makes up 0.000037% of the atmosphere's weight. It is contained in natural gas at a quantity of 2%.[12] Additionally, it can be found in the ore of some radioactive elements, including uranium and thorium. The freestate contains helium as well.[13] Helium has a negative effect on the body by causing

Flowchart 3: Properties and uses of Helium

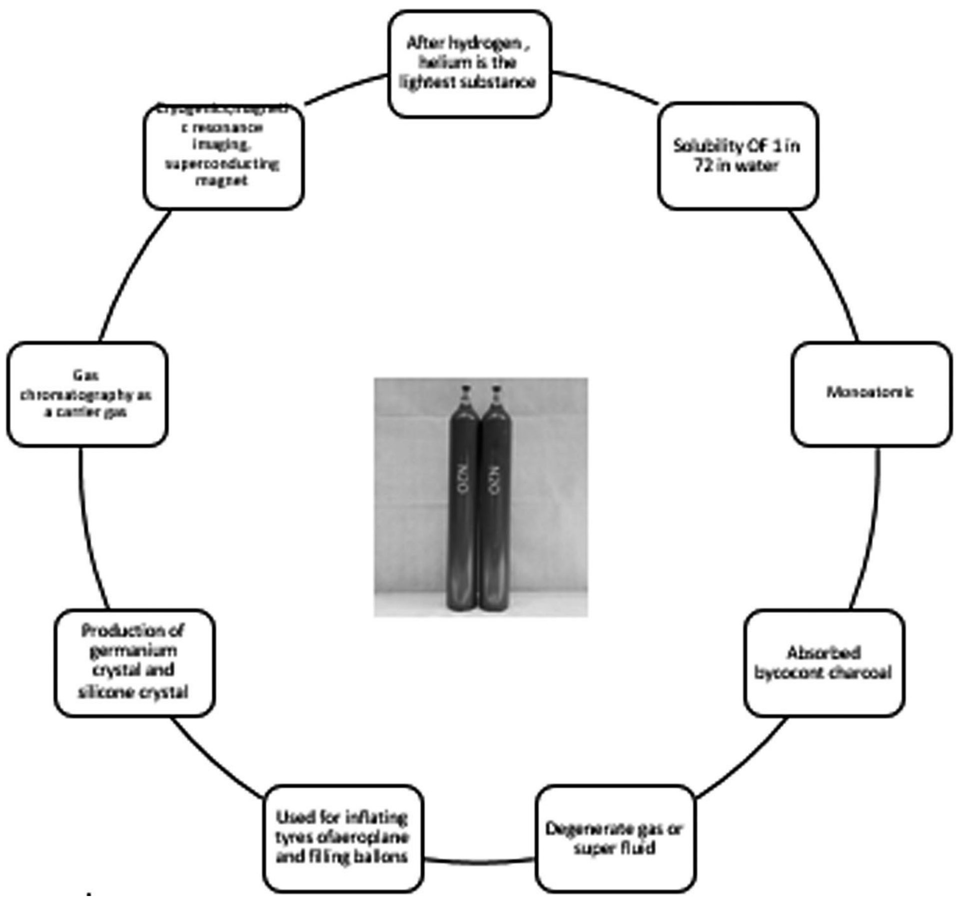


asphyxiation, which can result in loss of consciousness and anoxic death. Asphyxia symptoms include rapid and gasping breathing, rapid tiredness, nausea, vomiting, and cyanosis. It has been discovered that prolonged helium inhalation raises the vocal pitch and distorts the voice. After breathing in helium from a pressurised container, cases of cerebral artery gas embolism have been documented. It is safe to use during nursing and pregnancy.[14]

5. Nitrous Oxide as Medicinal Gas

The least effective inhalation anaesthetic is nitrous oxide. The effects of nitrous oxide on breathing and hemodynamics are negligible.[15] It is frequently referred to as laughing gas. This substance is a potent oxidant at high temperatures yet is insoluble in water. A small amount of it inhaled results in joy and bliss. At greater

Flowchart 4: Properties and uses of Nitrous oxide

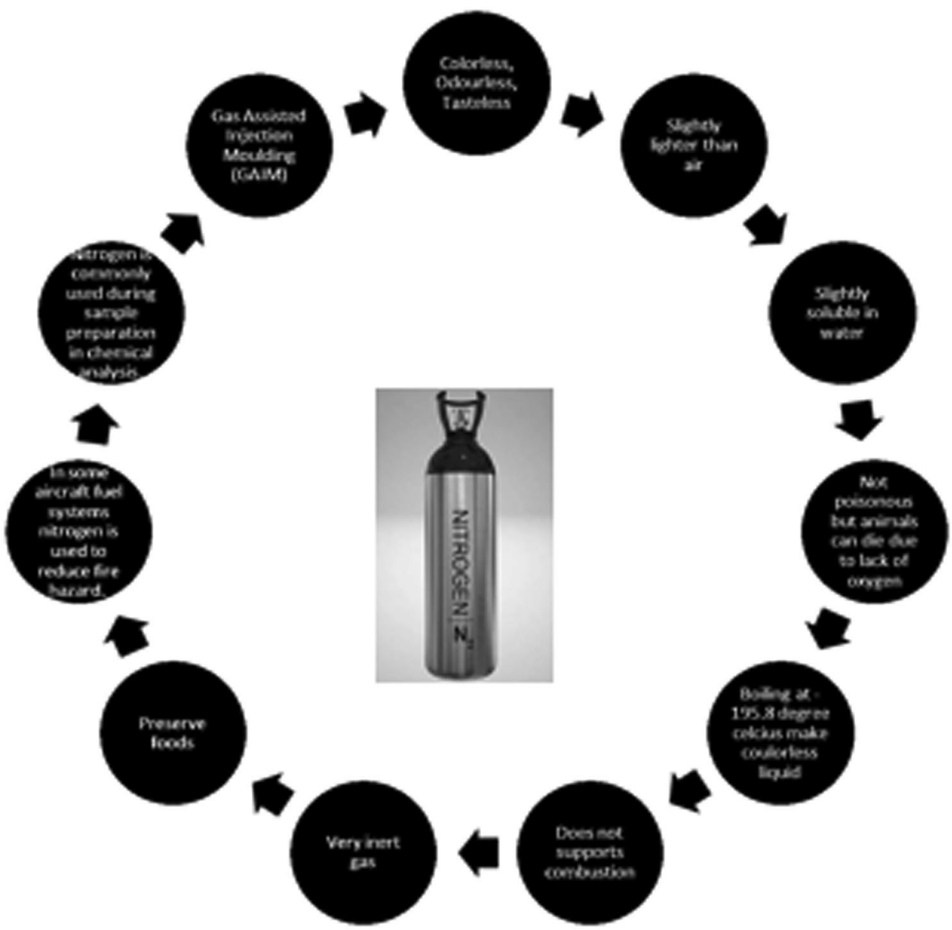


doses, it can have narcotic effects and cause suffocation death.[16] Without thorough clinical supervision and haematological monitoring, the negative effects of nitrous oxide should not be utilised for longer than a total of 24 hours or more frequently than every 4 days. Vitamin B12, a co-factor of methionine synthase, is rendered inactive by nitrous oxide.[5,6] As a result, prolonged nitrous oxide treatment interferes with folate metabolism and impairs DNA synthesis.[17]

6. Nitrogen as Medicinal Gas

79% of the atmosphere is composed of nitrogen. It is also present in significant amounts as white saltpetre ($NaNO_2$). In plant and animal tissues, it occurs as ammonia when combined with hydrogen as well as in organic combinations as proteins, amino acids, alkaloids, etc.[18] Additionally, nitrifying microorganisms

Flowchart 5: Properties and uses of Nitrogen



in the soil produce it as nitrates. Nitrogen has no known side effects, but it is not suggested that older patients with bronchitis use it to treat their condition. After using gas in high-pressure environments like deep diving, cases of nitrogen narcosis have been documented.[19]

7. Role of Combination Medical Gases in Therapy

a) Heliox[20]

Introduction: Heliox is a low density helium and oxygen gas mixture that is frequently utilised in critical care settings as well as deep diving. Furthermore, it has no known hazardous or carcinogenic effects and has no long-term consequences for any human organs.

Composition: The gas mixture known as heliox is made up of 21% oxygen and 79% helium.

Uses: It is used to treat croup, pnemonia, laryngeal blockage, and pulmonary rehabilitation.

b) Carbogen[21]

Combination: It is the mixture of 5% medical carbon dioxide in medical oxygen (CO_2/O_2).

Introduction: Carbogen also called Meduna's mixture of carbo dioxide and oxygen used to stimulate the respiration chronic respiratory disease.

Uses:

- It is used in the treatment of respiratory disease.
- It is used with nicotinamide in radiotheraphy to kill cancer cell.

c) Trimix[22]

Introduction: Trimix is a breathing gas consisting of oxygen, helium and nitrogen and is used in deep commercial diving,and in advanced recreational diving.

Combination: 10% oxygen, 70% helium, 20% nitrogen is suitable for a 100-metre (330 ft) dive.

Uses: It is useed in deep diving or scuba diving by deep divers.

d) Entonox[23]

Introdution: Entonox is a mixture of nitrous oxide and oxygen.It is to control pain and anxiety during some medical tests and procedures.

Combination: It is a combination of 50% nitrous oxide and 50% oxygen providing the inhalational analgesia.

Uses: It is used for short-term pain relief during labour and used to treat anxiety.

e) Nitrox[24]

Introdution: Nitrox refers to any gas mixture composed (excepting trace gases) of nitrogen and oxygen.

Combination: It is composed of 78% nitrogen, 21% oxygen, and 1% other gases, primarily argon.

Uses: It is commonly used in scuba diving, hyperbaric treatment of decompression illness.

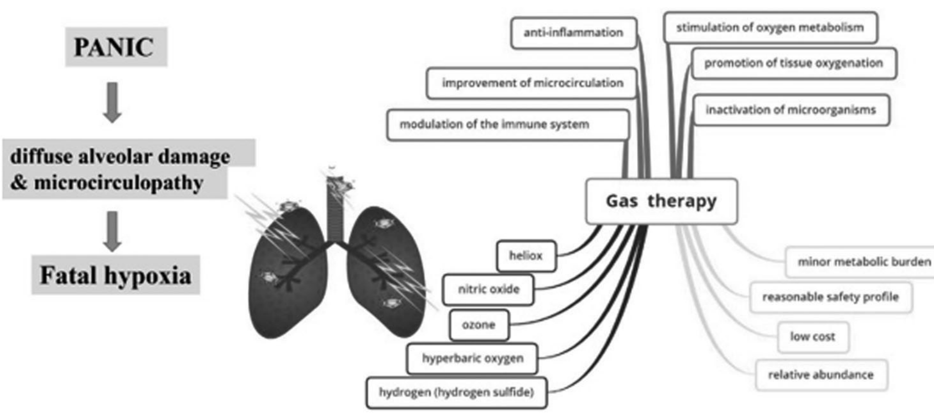
8. Combination Medical Gases Therapy in COVID-19

The body's oxygen levels can drop. Therefore, we must administer medical oxygen to maintain your oxygen levels within the usual range. Now, because every cell in the body needs oxygen for regular function, when your oxygen levels are low due to a condition like COVID-19, the body's cells don't have enough oxygen to do their usual functions.[25] Therefore, the cells themselves stop functioning properly if the oxygen levels are low, if they are low for a long period, and if it is not corrected. Cells may then start to perish when they entirely stop working. So you can see that the organs begin, your organs once, your organs, including your brain, heart, lungs, and kidneys, start. As a result, they will begin to malfunction, which in the worst situations can be fatal. Medical oxygen is, once more, the life-saving procedure here.[26] Medical oxygen, then, is oxygen that has been compressed from the air such that when you breathe it in, let's say, from a cylinder, it is virtually completely pure oxygen. And it is what we give patients to maintain normal blood oxygen levels.[27]

Technology is needed for medical oxygen. It implies that since there is oxygen in the air, you must be able to draw it. Oxygen makes up about 21% of the air. However, we must focus on medicinal oxygen, which calls for technology. Thus, that is a problem in several nations.[28] The actual distribution of medical oxygen presents another difficulty. Therefore, one is to concentrate oxygen and supply a hospital or a region with it. And distribution is the additional factor.

Therefore, ensure that the patients can access the oxygen you have produced and delivered. The third issue, in my opinion, is learning how to use medical oxygen, which entails maintaining the equipment, fixing any potential problems, and making sure the piping is in good working order.

The coronavirus disease 2019 (COVID-19) caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) caused a deadly pandemic that posed a grave threat to global health and forced researchers to look into effective remedies. More over 100 million people had contracted SARS-CoV-2 as of January 28, 2021, and over 2 million had perished as a result. Acute respiratory distress syndrome (ARDS), which is brought on by the "prolific activation of a network-immune-inflammatory crisis" (PANIC), is the primary clinical hallmark of individuals with severe COVID-19 who need ventilation. Although the pathophysiology of COVID-19 is not fully known, the lungs' pathological appearance differs greatly in terms of the microcirculopathy and diffuse alveolar destruction that result in life-threatening hypoxia. Acute care unit (ICU) admission is necessary for about 30% of COVID-19 patients, however there are no effective therapeutic treatments available.[29]



Picture 2: Combinational medical gases therapy in COVID-19[49]

9. Gas Therapies

9.1 Nitric Oxide

Through the activation of soluble guanylate cyclase (SGC) in the vascular smooth muscle, the therapeutic gas nitric oxide (NO) regulates blood flow and vascular tone, and it also has an impact on mitochondrial oxygen consumption by inhibiting cytochrome c oxidase.[30]

9.2 Ozone

Three oxygen atoms make up the molecule of ozone, an allotrope of oxygen. It has been emphasised that the human body may produce ozone to defend itself against a variety of pathogens.[31] Ozone is also a nuclear factor-B (NF-B) and nuclear factor erythroid 2-related factor 2 (Nrf2) transcription agent, which allows it to control the expression of genes related to inflammation and have anti-oxidizing and anti-inflammatory effects. Notably, the viral biology of SARS-CoV-2 is effectively destroyed by Nrf2-mediated inhibition of the fusion of the SARS-CoV-2 spike protein with the angiotensin-converting enzyme 2 receptor.[32] Conventionally, medical ozone (MO) therapy uses a mixture of 95–99% pure oxygen and 1–5% ozone gas.

9.3 Hyperbaric Oxygen

Due to increased oxygen diffusional resistance, conventional oxygen-supportive therapies are ineffective in COVID-19 patients. Only when elevated oxygen concentrations are made available to the tissue can the vicious loop that tightly links inflammation to hypoxia be broken. The patient receives intermittent exposure to approximately 100% oxygen during hyperbaric oxygen treatment (HBOT) in a chamber that is pressurised to at least 1.4 atmospheres.[33]

9.4 Hydrogen or Hydrogen Sulfide (H_2S)

Hydrogen is a crucial physiological regulatory component having anti-oxidative, anti-inflammatory, anti-apoptotic, and anti-allergic properties, according to current scientific and clinical studies. Inhaling hydrogen gas, drinking water that has had hydrogen dissolved in it, taking a hydrogen bath and injecting hydrogen-dissolved saline have all been found to have positive benefits on treating more than 38 diseases.[34] Endogenous production of hydrogen sulphide (H_2S) plays important physiological roles, including regulating inflammatory and host responses to viral infections. Growing evidence points to an inverse association between endogenous H2S levels and a number of illnesses, particularly COVID-19, however there are currently no confirmed medical uses for COVID-19 H_2S.[35]

9.5 Heliox

Since many years ago, heliox, a helium-oxygen gas mixture, has been utilised to treat chronic obstructive pulmonary disease (COPD). Heliox offers a solution to emergency airway issues and can greatly reduce airway resistance (Raw) when an anatomic airway obstruction is present because of its low density and high viscosity.[36] A case report[37] was the first to discuss the potential of employing heliox in individuals with COVID-19 in addition to its therapeutic role in acute asthma and COPD. After inhaling Heliox, an infected infant with severe acute respiratory distress responded rapidly and significantly, leading to an improvement in respiratory and general health. This gas combination should only be used as a stopgap measure to minimise Raw and respiratory muscle work until appropriate medications address the etiological causes because it may not treat the underlying condition or affect airway structure. Heliox has not yet been advised for frequent therapeutic use.[38]

10. Proven Effect of Medicinal Gases in Therapy

Gases	*Effects proven*	*Condition*	*Composition*	*Prove*	*Reference*
Ozone therapy	Its immunostimulating, antibacterial, anti-hypoxic, and biosynthetic properties make it a promising antiseptic adjuvant.	Immune response mechanism of the host and individual genetic factor	95% oxygen and 5% ozone gas	Standard periodontal treatment may be leveraged to promote the tissue healing response	Biagio Rapone *et. al*, 2022[39]
Carbon monoxide	platforms for cancer therapy, as well as multifaceted control of cellular activity and the tumour microenvironment	Biosafety problems arising from burst release and demand for high therapeutic concentrations in tumor cells	0.3% of carbon monoxide and medical air 99.7%	Future directions of carbon monoxide therapy are highlighted for future clinical translation	Yang Zhou *et. al*, 2020[40]
Hydrogen therapy used in inflammation of COVID-19	Inflammation, oxidative stress, apoptosis	Affects the alveolar type2 pneumocyte	66% hydrogen 33% oxygen	Preclinical and clinical studies have demonstrated the effects of hydrogen in varying diseases including covid -19	Duried Alwazeer *et. al*, 2021[41]
Oxygen therapy in urological diseases	Angiogenesis by endothelial proliferation, anti-inflammatory, macrophage activity, fibroblastic activity, and bactericidal effects	malignant tumour, non-healing conditions such ischemia, and radiation-induced tissue damage. pathological diseases such as interstitial cystitis and hemorrhagic cystitis	100% oxygen at a pressure of 200-250 kph	The role of hyperbaric oxygen therapy in refractory urological diseases that are resistant to conventional therapies	Tomoaki Tanaka *et. al*, 2019[42]

Contd…

Contd…

Gases	***Effects proven***	***Condition***	***Composition***	***Prove***	***Reference***
Hydrogen	Diverse animal models, and human disease	Metabolic syndrome, organ injury, cancer	A single proton and a single electron	Supporting hydrogen medicine in human disease prevention and therapy	Ming Yang *et. al,* 2017[43]
Argon	effects that protect organs and the nervous system. used ischemia models in vivo and in vitro	Brain trauma, cerebral ischemia, and hypoxic-ischemic encephalopathy	Argon	Argon neuro and organ protective effect and its possible mechanism of action	Anita Schug *et. al,* 2014[44]
Oxygen therapy used in traumatic brain injury	A severe brain injury's aftereffect is neurological impairment. For TBI, hyperbaric oxygen therapy is helpful.	Brain injury, traumatic impact, cerebral ischemic, vasospasm, edema	100% oxygen	The effectiveness and feasibility of HBOT have been confirmed by several studies. Application of HBOT is a cerebrovascular disease and TBI	Yang Wang *et. al*, 2014[45]
Oxygen – ozone therapy	Radicular dysfunction and autoimmune response with chronic inflammatory responses are impacted.	Oxidative stress, chronic oxidative injury	Oxygen and ozone	Oxygen-ozone gas injections are given to patients affected by cervical disc herniations	Alberto Alexandre *et. al,* 2005[46]
Radon	affected in sweat after being exposed to radon for medicinal purposes in a warm, muggy atmosphere	Spondyloarthropathy or non-inflammatory rheumatic disease	Radon	Skin is the major target for radon therapy because of the influence on Langerhans cell function	A Falkenbach *et. al,* 2000[47]

Conclusion

The medical gases oxygen, nitrous oxide, medical air, entonox, carbon dioxide, heliox, and nitric oxide are used in anaesthesia and intensive care. Breathable gases that are provided to patients are kept in cylinders or in bulk outside of the facility. A network of pipelines is then used to transmit medical gases around the facility. This study highlights the need of providing medical staff with practical training in how to administer the 50% N_2O/O_2 premix and verifies its pharmacological safety across a broad range of therapeutic reasons.

The healthcare systems of several nations collapsed as a result of the lung viral pandemic brought on by SARS-CoV-2, necessitating an urgent and quick search of safe and efficient therapeutic solutions.Their therapeutic potential is linked to anti-inflammatory activity, immune system regulation, improved microcirculation, microbe inactivation, promotion of oxygen metabolism, and increased tissue oxygenation. While we research new medications or wait for the widespread use of vaccines, gaseous therapy is a practical and affordable adjuvant therapy. To determine the effectiveness and safety of gas therapy for COVID-19 in terms of the necessity of invasive ventilation and durations of hospital and ICU stays, more extensive, well-controlled clinical trials are necessary.

Each nation has a regulatory body that keeps an eye on the production and application of medical gases. Additionally, they maintain that only trained professionals should handle these gases. To ensure that the national standards are adhered to throughout the nation, all countries included the medicinal gases and their containers in its monograph. Despite all of the regulatory agency's efforts, there are still tales of tragedies caused by the incorrect use of gases all over the world. Only a small sample of the recorded catastrophes is shown above. There may be a large number of unreported cases worldwide, particularly in developing nations with lax legal frameworks and inadequate documentation standards.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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5

Snake, Snakebite and It's Treatment in Ayurveda

Prof. (Dr.) Dilip Kr. Goswami

B.A.M.S, MD (Ayurveda), Ph.D.
Department of Agada Tantra (Toxicology, Forensic Medicine and Medical Jurisprudence)
Sri Sri College of Ayurvedic Science and Research Hospital
Sri Sri University, Cuttack, Odisha, India
(M): 9864351115, e-mail: drdilipgoswami37@gmail.com

ABSTRACT

Snakes are the common reptiles available around. Since time immemorial the human society is living with the snakes. Sometimes the snakes also caused harm to some of the humans as well as to some animals and other living organisms. Most of the snakes are not dangerous. They have no poison hence even when they bite it causes no harm. But some of them contain very strong poison and their bite may even cause immediate death. The bite of the poisonous snakes made the people afraid and, with the aim to get scared from their anger (bite), they were respected as divine ones. Till now some scientists are tirelessly working to understand the snakes, their venom, signs and symptoms of bite and treatment principles.

The Hindus respect the snakes as a group of creatures that are strong and dangerous. "MANASA" is considered as the goddess of snake and she is honoured accordingly by offering "PUJA" and "PRAYER".

Ayurvedic classics mention "SARPA" which is the class of creatures having some divine characters and strength. The Ayurvedic acharyyas (teachers – scholars) describe different aspects in relation to the "SARPA" elaborately with special reference to their classification, behaviour, bite, causes of fatal snakebite, diagnosis and treatment.

A discussion on the Ayurvedic concepts of snake (Sarpa) is seemed to have importance even in this era of science.

Keywords: Snake, bite of the poisonous snakes, treatment principles, Ayurvedic acharyyas.

Introduction

Charaka Samhita, Susruta Samhita, Ashtanga Hridaya and Ashtanga Sangraha are the important and oldest dependable classics containing the concepts of Ayurveda. Charaka Samhita, the oldest available book of medicine and Susruta Samhita is of

Surgery. Agnivesha, the author of Charaka Samhita documented the informations available till his time on aetiology, diagnosis, investigation and treatment of the diseases occurring due to improper/abnormal functioning of the Agni. Susruta, the author of Susruta Samhita, collected the informations available till his time related with the aetiology, signs and symptoms, diagnosis and treatment of the surgically curable diseases. The activity of Bagbhata in the form of Ashtanga Samgraha and Ashtanga Hridaya are the re - evaluated and expanded form of both the Charaka Samhita and Susruta Samhita. Bagbhata has mentioned almost all the contents of Charaka Samhita and Susruta Samhita and added some points from his own experience and observation.

Poison (BISHA) can be considered to be an important aetiology of many types of sufferings. In most of the conditions poisoning causes death. History gives the evidence of use of poison with the intention to cause harm to the enemies.

Among the poisons Charaka, Susruta and Bagbhata mentions " SARPA" (snake) as a potent source of poison. A detail description of the snakes, their venom, causes of snakebite and treatment is given in Charaka Samhita, Chikitsa sthana 23rd chapter sloka 35-37, 38,124 -139, 161-164, 194-198, 250-253, Susruta Samhita,Kalpasthana, chapter 3 sloka 28,29, 39, chapter 4 sloka 4-45, chapter 5 sloka 3-86 and Ashtanga Hridaya, Uttaraardha chapter 36,sloka 1-93. The concept of Ashtanga Sangraha and Ashtanga Hridaya can be considered as same.

In this study the concepts of Charaka and Susruta samhita is incorporated keeping the similarity of Ashtanga Sangraha and Ashtanga Hridaya with the concepts of these two valuable books in mind.

A discussion on the snakes with special reference to origin, types, character, poison, snakebite (causes,signs and symptoms) and treatment can open a new field in understanding the snakes and their venom.

Origin and Type of Snake

Snakes (Sarpa) is mentioned as a "Jangama Bisha".[1] They are said to be of 3 types depending upon the effect of the poison on the Tridosha – (1) Darvikara, (2) Mandali and (3) Rajiman.[2]

Depending upon the gender they are again classified into 3 groups – (1) Pung (male), (2) Stree (female) and (3) Kliba (neuter).[3]

Again depending upon some special characters they are cl;assified as (1) Brahmana, (2) Kshatriya, (3) Baishya and (4) Sudra.[4] This classification follows the classification of human society depending upon their profession.

Diagnosis of Poisonous Snakebite

Very interesting and justified advice for differential diagnosis of poisonous and non poisonous snakebite is available in the Ayurvedic classics. Examination of a snakebite patient is advised to be done in two steps – (1) local and (2) systemic. In the local examination colour, swelling, discharge, consistency etc. are advised to consider and in systemic examination colour of the skin, nails, teeth, eyes, stool, urine, ; condition of the voice, vision, stability of the body, neurological functions, response to command, status of sense etc. are advised to assess. Even the signs and symptoms are categorised as most poisonous and less poisonous.

Treatment of Snakebite (Bishachikitsa)

Charaka mentions 24 procedures of treatment of poisoning (Chaturvingsati Bisha Upakrama)[5] and advised that, these treatment procedures should be used selectively considering the applicability. The 24 treatment procedures are –

(1) Mantra (Chanting of verses) - Chanting of some prescribed verses is mentioned by Charaka as the first and foremost treatment in snakebite. In this process specially framed verses are chanted by the Vaidya following prescribed protocol.

MANTRA is said to be founded by the sages and knowledgeous persons. So, if used properly failure should not be there.[6]

(2) Aristabandhana (Benikabandhana) (application of tourniquet) - A ligature should be applied above the site of bite to prevent the spread of the injected poison.[7] Aristabandhana in poisoning is said to be like dam in river.[8]

When snakebite occurs on the shakha (extremities – hands or legs) a ligature (tourniquet) should be applied 4 anguli above the bitesite. The material advised to use for application of ligature are – gauze (plota), inner part of bark of tree (charmantabalka) or any other soft substance. This prevents (slows down) the speed of circulation of the poison to the other parts of the body.[9]

Aristabandhana is said to be more effective when it is applied by chanting MANTRA.[10]

(3) Utkartana (incision/excision) - Incisions should be applied on the bite site. If possible and feasible then the part where bitten should be excised.[11] Utkartana in poisoning is compared with the act of cutting the root of a tree. It completely stops the chance of spread of the poison.[12]

When snake bites in a part of the body where Aristabandhana is contra indicated the part, if possible, should be excised or incised. Excision should be followed by cauterization and incision by sucking and cauterization.[13]

(4) Nispidana (Sqeezing) - Blood should be expelled out by sqeezing the site of bite either applying incision or without application of incision.[14]

(5) Chushana (Sucking) - Sucking of blood through the bite injury or applied incision should be done to expel out the poisoned blood.[15] Chushana is said to be the procedure that brings the poison to the site of bite and then expelled out from the body.[16]

To conduct Achushana the oral cavity is advised to fill-up with soft cloth to prevent direct contact of the poisonous blood with the oral mucosa.[17]

This process is applicable if there is contra indication of Aristabandhana (if snakebite is on the head, neck, chest, abdomen, back etc.).[18]

(6) Agni (Cauterization) - When the poison remains in Twak and Mamsa (skin and muscles) then cauterization should be done which destroys the poison.[19]

Agnikarma is indicated when arishabandhana is contra indicated. The part should be cauterized by using hot probe or other hot substance.[20]

(7) Parisheka (Spraying) - The affected part should be treated with spraying of cold medicinal preparations that prevents the spread of poison through blood, as cold spray slows down the circulation of blood.[21]

(8) Avagaha (Bathing) - When poison spreads in Pittasthana then avagahana is advised.[22]

(9) Raktamokshana (Blood Letting) - The poisoned blood should be expelled out by using the procedures – (1) Pracchana, (2) Shringa, (3) Jalouka and (4) Siravedha. Raktamokshana expels out the poisoned blood and saves the life by preventing prakriti dusti.[23]

An expert physician should do venipuncture around the site of bite. If the poison spreads then venipuncture should be done in the hands or feet (Shakhagre) or in the frontal area of the head (Lalate). This can expel out the poisonous blood from the system which is said to be the most beneficial and important procedure in snakebite.[24]

In the Prathama vega of Darvikara sarpabisha this process is indicated.[25]

(10) Vamana (Induced Vomiting) - When the signs and symptoms suggest the reach of poison in Amashaya (stomach) this treatment is applicable.[26]

Vamana is considered as the procedure to expel out the poison from the system easily.[27]

Vamana is indicated in the Chaturtha vega of Darvikara Sarpabisha.[28]

(11) Bireka (Induced Purgation) - It is the procedure when the unwanted doshas (substances) are expelled out from the system through anal route by using medicines.

(12) Upadhana (Kakapada) (Application of Medicine on Incision over the Vertex) - In the state when Srotorodha occurs (disturbance in the functions of the circulatory channels) due to dushita Kafa (vitiated Kafa) then incision should be given on the vertex and fresh meat of goat, cow, buffalo, chicken etc. should be applied on the incision.[29] Kakapada is applicable in the vertex (mastaka) in adhodasta (bite on the lower part of the body) and in the pada (sole) in urdhadasta (bite on the upper part of the body).[30]

Kakapada is indicated in the Saptama vega of Darvikara bisha.[31] (Su. Ka. 5/23)

(13) Hridayavarana (Cardioprotection) - The Vaidya is advised to apply his effort to protect the heart of the patient of poisoning as the first step. For the purpose drinking of Honey, Ghee, Majja, Kshira, Gairika etc. is advised.[32]

(14) Anjana (Application of Medicine through the Eyes) - The patient of poisoning who suffers from difficulty in vision (Akshi uparodha) medicine should be applied around the eyes. For the purpose the paste prepared by mixing Daruharidra, Sunthi, Pippali, Marich, Haridra, Karavira patra, Karanja beeja, Neem beeja, Tulasi manjari with Chagamutra is adsvised.[33]

Anjana is indicated in the Tritiya vega of Darvikara sarpabisha.[34]

Anjana (tikshna) is indicated in the Saptama vega of Darvikara sarpa.[35]

(15) Nasya (Application of Medicines through Nostrils) - When the patient of snakebite suffers from disturbance in the functions of the nose, eye, ear, tongue and throat then medicine should be applied through the nostrils. For the purpose Bartaku (brinjal), Bijapura(citron), Jyotismati (intellect tree) are mentioned as the drugs of choice.[36] Nasya is indicated when bisha reaches and spreads in the Sirahpradesha (head). For the purpose fine powder of Bandhujivamoola (root of Pentapetes Phoenicea), Bhargimoola (root of Clerodendron Serratum) and surasamoola (root of Ocimum tenuiflorum) is advised.[37]

Nasya is indicated in the Tritiya vega of Darvikara sarpabisha.[38]

Nasya (Abapidana) is indicated in the Saptama vega of Darvikara bisha.[39]

(16) Dhuma (Use of Smoke) - Some drugs are burnt in fire and the affected part is exposed to the smoke. For the purpose Pita Sarsapa (yellow mustard), Chandana (sandal wood) etc. should be used.[40]

(17) Leha (Application of Lickable Medicines) - When poison affects the throat (kanthapradesha) and produces the symptoms like hoarseness of voice (swarabheda), speaking disability (kanthanasha) then amakapittha beeja churna (powder of unripe wood apple) should be licked with sugar.[41]

(18) Aushadha - Means and indicates use of specially prepared medicines that act against the condition.

(19) Prasamana - Indicates the use of medicines that can pacify the affected dosha.

(20) Pratisarana - Local application of powdered medicine specially when there is external contact of the poison.

(21) Pratibisha (Agadaprayoga) (use of antidote) - In the Dwitiya vega of Darvikara sarpabisha madhusarpiyukta agada (antidote with honey and ghee) is indicated.[42]

(22) Sajnasangsthapana (Resuscitation) - This process is to be applied in the 6th vega of poisoning. For the purpose Gopitta (bile of cow) and powders of Haridra (turmeric), Manjistha(Indian Madder), Maricha(Black Pepper), Pippali (Long pepper) in equal quantity with water is advised.[43]

(23) Lepa (local application of medicine) - In this process the medicinal pastes are used on the affected part.

(24) Mritasanjivana - This is the procedure to be applied at the terminal stage of the patient when he/she is in deep coma stage and seems to be dead (mrita Avastha).

Prognosis

Prognosis of snakebite is said to be dependent upon a number of factors like, type and condition of snake, body part where the bite occurred, condition of the victim in relation to age, sex, nutritional status, disease, psychological status etc. A relation with the place where bite occurred, the situation of the planets at the time of bite, astrological day etc. are also mentioned with priority.

Prevention

Snakebite is advised to prevent by using specific type of stick during the night hours, umbrella during the day time and wearing of some valuable gems.[44]

Discussion

The important points to be discussed from the above description are –

(1) The concepts of the Ayurvedic classics on snake as of divine origin is a matter of discussion. When the classification of snake is observed then it is noticed

that, the basis are taken as the presence/absence of hood, it's shape, body colour, appearance, resemblance of the structures available on the body, time of movement, character of movement (slow/quick), appearance of specific dosha related signs and symptoms after bite etc. In modern discussions divine origin concept is not available. The classification of the snakes is made basically basing upon the head scale pattern and body scale pattern.

(2) For diagnosis of snakebite it seems brilliant and easy to classify initially as poisonous and non poisonous, then more poisonous and less poisonous and ultimately,if poisonous what dosha is primarily and seriously affected (Darvikar/Mandali/Rajiman). Simple categorization of a disease state makes treatment easy. The modern classification of snake in view of treatment is also Made simple to determine which type of Anti venom is to be used.

(3) The treatment procedures are mentioned as 24 in number in the Ayurvedic classics which seems to be more elaborate. In the advice to the physicians related with treatment of snakebite it is said that, at the time of installation of treatment to a patient of snakebite a group of procedures should be selected by the physician depending upon the age, sex, condition etc. of the patient, type of the snake and many other conditions for which adequate detail knowledge and experience of the physician is must.

(4) Mantra is mentioned as the 1st one among the 24 treatment methods of poisoning. Modern toxicology is not admitting the utility of mantra in any type of treatment. But, new researches are going on to understand the effect of mantra on the person. Ayurveda says that mantra should be chanted by a person who leads his life under strict rules and regulations and always keeps himself away from alcoholic drinks, meat, contact with females etc. To understand it's effect one can think in the line of boosting of psychological strength which can be considered to be 50% advancement in the way of cure. As studies say that, most of the casualties of snakebite is due to fear to get envenomated even not being bitten by poisonous snake.

(5) In case of some other treatment procedures mentioned by the Ayurvedic classics also there is direct opposition of the modern toxicologists. But when studied in detail it becomes clear that their utility also can be established basing upon the classical concepts.

Summary

As summary the following points can be mentioned –

(1) The Ayurvedic scholars were vigilant and enthusiastic on the study, analysis and discussion on the snakes.

(2) Samhitas like Charaka, Susruta, Ashtanga Hriday and Ashtanga Sangraha are the potent sources of detail knowledge about the snakes with special reference to their origin, character, poisoning, bite and treatment. But, considering close similarity in the descriptions the concepts only Charaka and Susruta is incorporated in this study.

(3) Detail study, research and evaluation of the descriptions in the Ayurvedic classics can explore many valuable facts about the snakes and their effect on human beings.

Conclusion

As conclusion it can be said that, time demands detail study, research and evaluation of the Ayurvedic concepts on snakes for which multi disciplinary efforts should be applied by dedicated teams which may be proved to be an invaluable boon to the human society.

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6

Understand Natural Urges to Remain Healthy

Prof. (Dr.) Dilip Kr. Goswami

B.A.M.S, MD (Ayurveda), Ph. D
Dept. of Agadatantra (Toxicology, Forensic Medicine and Medical Jurisprudence)
Sri Sri College of Ayurvedic Science and Research Hospital
Sri Sri University, Cuttack, Odisha, India
(M)- 9864351115, E-mail – drdilipgoswami37@gmail.com

ABSTRACT

Natural urges are the feelings of the livings that indicate the need of expulsion of some unwanted products from the body produced during the process of digestion and include the urge of faeces, urine etc. The lower class animals expel out the excretable substances from the system without delay just feeling the urge. But human beings, being the intelligent living object with a number of engagements in different fields, in most of the times, cannot allow these urges to be fulfilled at proper time. In most of the situations it is observed that, the feeling of the desire of the body to expel out the unwanted substances (excreta) is to be suppressed.

Study of the Ayurvedic classics reveals that, the ancient Indian scholars of health science (Ayurveda Maharshis) kept more concern with some physiological indicators of the body suggesting to do some works at certain times. Some indicators of this category are related with the demand of the physiology to get rid of some excreta and some are related with the demand of the body to re - energizize for future whereas some are related with some mental and physical faculties that, if not controlled, can lead to some harmful situations. Very interestingly they advice the individual to not to suppress some of them (Adharaniya vega) and suppress some of them (Dharaniya vega) to acquire health, peace and harmony.

A discussion on these 2 groups of urges can be considered as valuable and important to create health awareness not only among the health workers but also among the common people.

Keywords: Natural urges, lower class animals, Ayurvedic classics, adharaniya vega, dharaniya vega.

Introduction

Health is indicated by the factors like, proper food intake, proper digestion,proper nutrition and proper excretion. Any abnormality in terms of quality, quantity and frequency indicates imbalance in the normal functioning of the respective organs/ systems which, in course of time, can lead to disease. After study and observation of the fact the Ayurvedic scholars identified a group of non suppressible natural urges and advised to act as per the demand of the system with scientific explanation. A discussion on the topic is made here with possible scientific justifications hoping to be helpful not only for the health workers but also for the scientists and common people. Here the concepts of the 4 main books Charaka Samhita, Susruta Samhita, Ashtanga Hridaya and Ashtanga Sangraha are taken into account.

To get an instant knowledge on the non suppressible group of natural urges the following table is incorporated –

S.No.	*Charaka Samhita (Sutrasthana, Chapter 7, Sloka 3,4)*	*Susruta Samhita (Uttaratantra, Chapter 55, Sloka 4,5)*	*Ashtanga Hridaya (Sutrasthana, Chapter 4, Sloka 1)*	*Ashtanga Sangraha (Sutrasthana, Chapter 5, Sloka 3)*
1	Mutra	Vayu	Vata	Vata
2	Purisha	Bin	Bin	Bin
3	Retas	Mutra	Mutra	Mutra
4	Vata	Jrimbha	Kshavathu	Kshavathu
5	Cchardi	Ashru	Trishna	Trit (Trishna)
6	Kshavathu	Kshavathu	Kshudha	Kshudha
7	Udgara	Udgara	Nidra	Nidra
8	Jrimbha	Bomi	Kasa	Kasa
9	Kshudha	Indriya(sukra)	Shramaswasa	Shramaswasa
10	Pipasa	Kshudha	Jrimbha	Jrimbha
11	Bashpa	Trishna	Ashru	Ashru
12	Nidra	Swasa	Cchardi	Cchardi
13	Nihswasa	Nidra	Retasa	Retasa (Shukra)

Basing upon the initial exposure a detail discussion on the group of natural urges seems to be useful and informative. The discussion on the concepts is incorporated below –

(**A) CHARAKA SAMHITA** – Charaka describes the manifestations and treatment of the situations as follows –

(1) MUTRAVEGARODHA (suppression of urge of urine)– manifestations – vastishoola (pain in the urinary bladder region), mehanashoola (pain in the urethra – genital organ), mutrakricchra (difficulty in urination), shiroruja(headache),Vinama(bending of the body), Vangshana anaha(swelling in the inguinal region) etc.[1]

Treatment – swedana (fomentation), avagahana(tub bath), abhyanga(message), sarpi avapidana(application of ghee through nostrils), niruha–anuvasana(application of enema) and Uttara basti prayoga(application of medicine through urethra).[2]

(2) PURISHAVEGARODHA (suppression of urge of stool)– manifestations – pakwashayashoola (pain in the intestinal region), shirahshoola(headache), Vata apravartana(non elimination of flatus), Varsho apravartana(non elimination of stool), pindikodwestana(pain in the calf muscles), adhmana(flatulence).[3]

Treatment – swedana(fomentation), abhyanga(massage), avagahana(tub bath), Vartiprayoga(application of suppository), Bastikarma (enema), pramathi (vat anuloman) annapana(use of foods and drinks that helps in appropriate elimination of flatus and stool).[4]

(3) SUKRAVEGARODHA (suppression of urge of semen – sexual desire)– medhrashoola(pain in the genital organ), vrishanashoola(pain in the testicles), angamarda(feeling of pain in the body),hridvyatha(pain in the heart region), mutra bibaddhata(retention of urine).[5]

Treatment - abhyanga (massage), avagahana (dronisnana) (tub bath), madirapana (taking of wines), charanayudha (kukkuta mamsa)(taking of chicken soup), shali (rice of nonboiled rice), paya (dugdha)(milk), niruha basti (purificatory enema), maithuna (sexual intercourse).[6]

(4) VATANIGRAHA (suppression of urge of flatus)– Bitsanga (retention of stool), mutrasanga (retention of urine), vatasanga (retention of flatus), adhmana (flatulence), bedana (pain, specially of abdomen), klama (tiredness).[7]

Treatment – snehana (oleation), swedana(fomentation), falabarti(application of suppository), basti(enema), vatanulomana ahar and bihar(food and drink that helps in proper elimination of stool, flatus etc.).[8]

(5) CCHARDINIGRAHA (suppression of urge of vomiting) – kandu(itching), kotha(eruption), aruchi(anorexia), vyanga (black spots on the cheeks), sotha (oedema), pandu (paleness-anaemia), jwara (rise of temperature), kustha (skin diseases), hrillasa (nausea), bisarpa (skin disease of quick spreading nature).[9]

Treatment – pracchardana (induced vomiting), dhumapana (application of medicated smoke), langhana (fasting), raktamokshana (blood letting), rukshannapana (use of food and drink that can cause dryness), vyayama (exercise), birechana (induced purgation).[10]

(6) KSHAVATHUVEGARODHA (suppression of urge of sneez)– manyastambha (torticollis), sirahshoola (headache), Ardita (facial palsy), ardhavabhedaka (hemicrania), indriyadaurbalya (weakness of the sense organs).[11]

Treatment – abhyanga and swedana in urdhajatru(massage on the upper portion of clavicle), dhumapana(use of medicated smoke), nasya(nasal drop), vataghna bhojana(use of food that can pacify vata), uttarabhaktika gritapana (taking ghee after food).[12]

(7) UDGARAVEGARODHA (suppression of urge of eructation) – hikka(hiccough), swasa(breathing difficulty),aruchi(anorexia), kampa(trembling), hridbibandha (feeling of tightness in the heart region), urobibandha(feeling of tightness of the chest).[13]

Treatment – same as hikka[14]

(8) JRIMBHAVEGARODHA (suppression of urge of yawning) – binama (bending of the body), akshepa (convulsion), sankocha (spasmodic pain), supti (numbness), kampa (trembling), prabepana(bending of the body).[15]

Treatment – Vatanashaka upachara (all treatment should be aimed to pacification of vata).[16]

(9) KSHUDHAVEGANIGRAHA (suppression of the urge of hunger) – Karshya(emaciation), daurbalya (weakness), baibarnya (loss of colour of the body), angamarda (pain of the body), aruchi (anorexia), bhrama(delirium).[17]

Treatment – Snigdha-ushna upachara (use of oily and warm management procedures) and laghubhojana (light food).[18]

(10) PIPASAVEGARODHA (suppression of the urge of thirst) – kanthashosha (dryness of the throat), ashyashosha (dryness of mouth), badhiryya (deafness-difficulty in hearing), bhrama (delirium), angasada (feeling of weakness of the body), hridvyatha (pain in the heart region).[19]

Treatment – Shita tarpana(nutritive food and drinks in cold form).[20]

(11) BASHPAVEGANIGRAHA (suppression of urge of lacrimation) – pratishyaya (coryza), akshiroga(eye disease), hridroga(heart disease), aruchi(anorexia), bhrama(delirium).[21]

Treatment – nidrasevana(sleeping), madyasevana (taking of wine), priyakatha (listening to good conversations).[22]

(12) NIDRAVEGARODHA (suppression of urge of sleep) – jrimbha(yawning), angamarda(pain of the body), tandra(drowsiness), shiroroga (headache and other diseases related to head), akshigaurava(heaviness of the eyes).[23]

Treatment – nidrasevana(sleeping) and sangbahana(application of mild massage on the body).[24]

(13) SWASAVEGARODHA (suppression of urge of breath due to exercise) – Gulma(tumour), hridroga(heart disease), sanmoha(feeling of drowsiness – semi consciousness).[25]

Treatment – bishrama (rest), vataghna kriya (application of treatments that pacify vata).[26]

(B) SUSRUTA SAMHITA – Maharshi Susruta, the father of surgery, in Susruta Samhita, discussed on the Adharaniya vega vividly. His opinion on this topic is discussed below -

(1) VAYUVEGARODHA (suppression of urge of flatus)- adhmana(flatulence), shoola(pain -in the abdomen), hridayoparodha(feeling of obstruction of the heart – chest), shiroruja(headache), hikka(hiccough), kasa(cough), pratishyaya(coryza), galagraha(feeling of obstruction of the throat), balasapittaprasara(aggravation and spread of kafa and pitta), purishakshaya(loss of stool quantity), mukhat purishapravritti (expulsion of stool through mouth).[27]

Treatment – Snehana(oleation therapy), swedana(fomentation) and asthapana basti (purificatory enema).[28]

(2) PURISHAVEGARODHA (suppression of the urge of stool) – Atopa(abdominal sound), shoola(abdominal pain), parikartana(cutting pain in the anal region), purishasanga(retention of stool), urdhavata [udgara](movement of vayu towards upwards – eruction), ashyat purishanirgamana (expulsion of stool through mouth).[29]

Treatment – like anaha(all the treatments of flatulence are applicable).

(3) MUTRAVEGARODHA (suppression of the urge of urine) – kricchramutrata (dysuria), alpamutrata(oliguria), medhra-guda-bangshana-basti-mushka-nabhi-murdhashoola(pain in the genital organ – anal region – inguinal region – bladder region – testicles – umbilical region and head), anaddhabasti (fullness of the urinary bladder), shoola(pain of the whole body).[30]

Treatment – ashmaribhedanchikitsa (all the treatments of urinary calculi are applicable).[31]

(4) JRIMBHAVEGARODHA (suppression of urge of yawning) – manyastambha (torticollis), galastambha(stiffness of the neck), shirobikara (diseases related with head), vatajaroga (diseases due to vata vitiation), shrotra-anana-ghrana-bilochanottha tibraroga (severe diseases related to ear, face, nose and eye).[32]

Treatment – snehana (oleation), swedana (fomentation).[33]

(5) ASHRUVEGARODHA (anandaja/shokaja) (suppression of the urge of lacrimation – due to happiness/grief)– Shirogurutwa (heaviness of the head), nayanamaya (diseases of the eye), pinasa (discharge through nostrils).[34]

Treatment - snehana (oleation), swedana (fomentation), ashrumokshana (induced lacrimation).[35]

(6) KSHAVATHUVEGARODHA (suppression of urge of sneez) – shiro-akshi-nasa-shravana roga (diseases of the head,eye, nose and ear), kantha-asyapurnatwa tatha tibratoda (feeling of fullness of throat and mouth with acute pain),kujana (sound during respiration), swasa apravritti (swasa avarodha) (feeling of obstruction of respiration).[36]

Treatment – tikshna anjana (strong collyrium), abapidana nasya (application of strong medicines through nostrils), tikshnasevana/nasabartiprayoga (intake of strong irritant substances/application of nasal suppository), kshavathu utpadana (induced sneez).[37]

(7) UDGARAVEGARODHA (suppression of urge of eructation) - tibra pavanavikara (may cause acute severe signs and symptoms indicating vitiation of vata).[38]

Treatment – dhuma-nasyaprayoga (application of medicated smoke and medicines through nostrils), kabalagraha (use of medicated gargle).[39]

(8) CCHARDIVEGARODHA (suppression of urge of vomiting) – kustha (skin diseases).[40]

Treatment – jathadosha snehaprayoga (use of oils according to vitiated dosha), abhyanga (massage).[41]

(9) SHUKRAVEGARODHA (suppression of urge of semen - sexual urge) – shofa and ruja in mutrashaya, payu and mushka (swelling and pain of the bladder region, anal region and testicles), mutrabinigraha (anuria/oliguria), shukrashmari (semen calculi).[42]

Treatment – bastishuddhi (purification of the urinary bladder – use of diuretics), priyanariramana (sexual act with beloved female).[43]

(10) KSHUDHAVEGARODHA (suppression of urge of hunger) – tandra (drowsiness), angamarda (pain of the body), aruchi (anorexia), bibhrama (delirium), drishtikrishata (visual weakness).[44]

Treatment – snigdha-ushna-alpa bhojana (intake of oil mixed, hot food in less quantity).[45]

(11) PIPASAVEGARODHA (suppression of urge of thirst) – Kanthashosha (dryness of throat), Ashyashosha (dryness of mouth), Shrabanavarodha (weakness in hearing), hridvyatha (pain in the heart -chest region).[46]

Treatment – shitala mantha or yavagu pana (taking of cold medicated preparations).[47]

(12) NIHSWASAVEGARODHA (suppression of the urge of respiration due to physical exercise) – hridroga (heart diseases), moha (clouding of sense), gulma (tumour).[48]

Treatment – bishrama (rest) and mamsarasayukta bhojana (intake of food with meat soup).[49]

(13) NIDRAVEGANIGRAHA (suppression of urge of sleep) – jrimbha (yawning), angamarda (body pain), angajadya (feeling of stiffness of body), shirojadya (feeling of stiffness of head), akshijadya (feeling of heaviness of the eyes), tandra (drowsiness).[50]

Treatment – dugdhapana (intake of milk), nidrasevana (sleeping), ishtakathasravana (listening to good and sweet stories/talking with beloved persons).[51]

(C) ASHTANGA HRIDAYA – The concept of Adharaniya vega as discussed in Bagbhatkrita Ashtanga Hridaya is as follows -

(1) ADHOVATARODHA (suppression of urge of flatus) – gulma (tumour), udavarta (obstruction of flatus, stool etc. with flatulence), ruk (sarbasaharira) (pain of the whole body), klama (feeling of tiredness), vata-mutra-shakritsanga (retention of flatus, urine and stool), drishti-agnibadha (reduced vision and digestive capacity), hridgada (heart diseases).[52]

Treatment – barti (use of suppository), abhyanga (massage), avagaha (tub bath), swedana (fomentation), basti (application of enema).[53]

(2) PURISHAVEGARODHA (suppression of urge of stool) – pindikodwestana (spasm of caff muscles), pratishyaya (sneezing), shiroruja (headache), urdhavayu (upward movement of vayu – eructation), parikartika (cutting pain in the anal region), Hridaya uparodha (feeling of obstruction in the heart-chest region), mukhena bitpravritti (expulsion of stool through mouth).[54]

Treatment – barti (application of suppository), abhyanga (massage), avagaha (tub bath), basti (enema), bingbhedi annapana (use of food and drink that softens and eliminates stool easily).[55]

(3) MUTRAVEGARODHA (suppression of urge of urine) – angabhanga (breaking pain of the body), ashmari (renal calculi), vasti-medhra-bangsanavedana (pain in the urinary bladder, genital organ and inguinal region).[56]

Treatment – barti (use of suppository), abhyanga (massage), avagaha (tub bath), basti (enema), bhojanapurba ghreetapana (taking of ghee before food).[57]

(4) UDGARAVEGARODHA (suppression of urge of eructation) – aruchi (anorexia), kampa(trembling), hridbibandha(feeling of obstruction of the functions of the heart), urobibandha(feeling of tightness of the chest), adhmana(flatulence), kasa (cough), hidhma(hikka)(hiccough).[58]

Treatment – like hikka (same treatment as advised in suppression of urge of hiccough).[59]

(5) KSHAVATHUVEGARODHA (suppression of urge of sneez)– shiroarti (headache), indriya daurbalya (weakness of the sense organs), manyastambha (torticollis), ardit (facial paralysis).[60]

Treatment – Snehana (oil message), swedana (fomentation), tikshna dhooma (application of strong medicated smoke), Tikshna Anjana(application of strong medicated collyrium), nasya(application of strong medicines through nostrils), arkabilokana(looking towards the Sun).[61]

(6) TRISHNAVEGARODHA (suppression of urge of thirst)– shosha(feeling of dryness), angasada(weakness of the body), badhirya(deafness), sammoha (drowsiness), bhrama(delirium), hridroga(heart disease).[62]

Treatment – Sarbaprakar shitakriya (all types of cold applications should be applied).[63]

(7) KSHUDHAVEGARODHA (suppression of urge of hunger)– Angabhanga (feeling of breaking of the body), aruchi(anorexia), glani(depression), karshya (emaciation), shoola(pain), bhrama(delirium).[64]

Treatment – laghu, snigdha, alpabhojana (taking of light, oily food in less quantity frequently).[65]

(8) NIDRAVEGARODHA (suppression of urge of sleep)– moha (drowsiness), murdhagaurava (heaviness of head), akshigaurava (heaviness of eye), alashya (lathergy), jrimbha(yawning), angamarda(feeling of pain in the body).[66]

Treatment – nidrasevana(sleeping) and sangbahana(gemtle massage over the body).[67]

(9) KASAVEGARODHA (suppression of urge of cough) – kasavriddhi(increase of cough), swasa(breathing difficulty), aruchi(anorexia), hridroga(heart disease), shosha(thirst), hikka(hiccough).[68]

Treatment – kasaha chikitsa(all treatments should be aimed to reduce cough).[69]

(10) SRAMASWASA VEGARODHA (suppression of breath due to exercise) – gulma(tumour), hridroga(heart disease), sanmoha(drowsiness).[70]

Treatment – Bishrama(rest), vataghna kriya(all treatments to pacify vata).[71]

(11) ASHRUVEGARODHA (suppression of urge of lacrimation) – pinasa (coryza), akshiroga (eye disease), shiroroga (diseases of head), hridroga (heart disease), manyastambha (torticolis), aruchi (anorexia), bhrama (delirium), gulma (tumour).[72]

Treatment – nidra(sleep), madya(wine), priyakatha(listening to good, sweet speech).[73]

(12) CCHARDIVEGARODHA (suppression of urge of vomiting) – bisarpa(skin disease with quick spreading nature), kotha(eruption), kustha(skin diseases), akshiroga(eye disease), kandu(itching), pandu(paleness – anaemia), jwara(rise of temperature), kasa(cough), swasa(breathing difficulty), hrillasa(nausea), vyanga(black spots on the cheeks), swayathu(oedema).[74]

Treatment – gandusha (gargling), dhuma(medicated smoke), bomi after taking rukshabhojana(induced vomiting after taking dry food), vyayama(exercise), raktamokshana(blood letting), birechana(purgation), lavana-ksharamisrita toilabhyanga(massage with salt and alkali mixed oil).[75]

(13) SHUKRAVEGARODHA (suppression of urge of semen -sexual desire) – sukrasravana(ejaculation), guhyabedana(pain in the genital organ, testicles etc.), swayathu(oedema), jwara(rise of temperature), hridvyatha(pain in the heart region – chest), mutrasanga(retention of urine), angabhanga(breaking pain in the body), vriddhi(hernia), ashmari(calculi), shandhata(impotency).[76]

Treatment – tamrachudamamsa(chicken), sura(wine), shali anna sevana(rice of unboiled crop), basti(enema), abhyanga(massage), avagahana(tub bath), bastishuddhikara kshira(milk preparation that can clean the urinary bladder), maithuna with Priya stree(sexual act with beloved female).[77]

(D) ASHTANGA SANGRAHA – Ashtanga Sangraha consists the description of Adharaniya Vega as follows -

(1) ADHOVATA VEGARODHA (suppression of urge of flatus) – Gulma(tumour), udavarta(flatulence), ruja(pain), klama(drowsiness), vata-mutra-shakritsanga(suppression of flatus, urine and stool), Drishti-agnibadha(weakness of vision and digestive capacity), hridgada(heart disease).

Treatment – Snehana(oleation), swedana(fomentation), bartiprayoga(application of suppository), vatalomana pana and bhojana(use of food and drink that help in easy elimination of flatus) and bastiprayoga(enema).[78]

(2) SHAKRIT VEGARODHA (suppression of urge of stool) – pindikodwestana(cramp in the calf muscle), pratishyaya(sneez with nasal discharge), shiroruja(headache), urdhavayu(upward movement of vayu – eructation), parikartika(cutting pain in the anal region), Hridaya uparodha(feeling of obstruction in the functions of the heart), mukhena bitpravritti(expulsion of stool through mouth).[79]

Treatment – bartiprayoga(application of suppository), abhyanga(massage), avagaha(tub bath), swedana(fomentation), basti(enema), bingbhedi annapana(use of food and drink that helps in easy elimination of stool).[80]

(3) MUTRAVEGARODHA (suppression of urge of urine)– Angabhanga(feeling of breaking pain of the body), ashmari(calculi), basti-medhra-bangshana Vedana(pain in the urinary bladder, genital and inguinal region).[81]

Treatment – pragbhakta ghritapana (taking of ghee before food), jirnantika ghritapana (taking ghee after digestion).[82]

(4) UDGARAVEGARODHA (suppression of urge of eructation)- Aruchi (anorexia), kampa(trembling), hridbibandha(feeling of compression on the heart region), urobibandha(feeling of compression of the chest), adhmana(flatulence), kasa(cough), hikka(hiccough).[83]

Treatment – As hikka (all treatments applicable in hiccough should be applied).[83]

(5) KSHAVATHUVEGARODHA (suppression of urge of sneez)– Shiro arti (headache), indriya daurbalya (weakness of sense organs), manyastambha (torticollis), Ardita (facial paralysis).[84]

Treatment – tiksnadhooma(use of strong medicated smoke), Tikshna Anjana(strong collyrium), Tikshna ghrana(smelling of strong smell), Tikshna nasya(use of strong medicines through nostril), arkabilokana (kshavathu pravartana)(induce sneez by looking towards the Sun), swedana(fomentation), abhyanga(massage), vataghna anna(taking of food with the property that pacify vata), uttarabhakta ghritapana(taking of ghee after food).[85]

(6) TRISHNAVEGARODHA (suppression of urge of thirst)– Shosha (feeling of dryness), angasada (weakness of the body), badhiryya (deafness), sammoha (drowsiness), bhrama (delirium), hridgada (heart disease).[86]

Treatment – sarbaprakara shitala vidhi (use of food and drink in cold form).[87]

(6) KSHUDHAVEGARODHA (suppression of urge of hunger) – angabhanga(feeling of breaking like feel of the body), aruchi(anorexia), glani(depression), karshya(emaciation), shoola(pain), bhrama (delirium).[88]

Treatment – laghu, snigdha, ushna, alpabhojana(taking of light, oily, warm and less quantity food).[89]

(7) NIDRAVEGARODHA (suppression of urge of sleep)– moha(drowsiness), murdhagaurava(heaviness of head), akshigaurava(heaviness of eyes), alasya(lathergy), jrimbha(yawning), angamarda(feeling of pain of the body).[90]

Treatment – swapnasevana (sleeping), sangbahana(massaging of the body gently).[91]

(8) KASAVEGERODHA (suppression of urge of cough) – kasavriddhi (increase of cough), swasa (breathing difficulty), aruchi (anorexia), hridamaya (heart disease), shosha (thirst), hidhma (hikka) (hiccough).[92]

Treatment – Kasahara vidhi (all treatments should be given to reduce cough)

(9) SHRAMASWASAVEGARODHA (suppression of urge of breath due to exercise) – gulma (tumour), hridroga (heart disease), sammoha (drowsiness/ clouding of consciousness).[93]

Treatment – bishramana (rest), vataghna kriya (all treatments should be installed to reduce vata).[94]

(10) JRIMBHAVEGARODHA (suppression of yawning)– All signs and symptoms of kshavathu vega rodha appears(same signs and symptoms as that of suppression of urge of sneez).[95]

Treatment – like kshavathu vega rodha chikitsa(treatment like the treatment advised in suppression of sneez).[96]

(11) BASHPAVEGARODHA (suppression of urge of lacrimation)– pinasa(nasal discharge), akshiroga (eye disease), shiroroga(diseases of the head), hridroga(heart disease), manyastambha(torticollis), aruchi(anorexia), bhrama (delirium), gulma(tumour).[97]

Treatment – swapna (sleeping), madyapana (taking of wine), priyakatha sravana (listening to sweet and good speeches, talking on good things etc.).[98]

(12) BAMANAVEGARODHA (suppression of urge of vomiting) – bisarpa, kotha, kustha(different types of skin diseases/appearance of eruptions etc.), akshikandu (itching of the eyes), pandu(paleness), jwara(rise of temperature), kasa (cough), swasa(breathing difficulty), hrillasa(nausea, palpitation), vyanga(black spot on the cheeks), swayathu(oedema).[99]

Treatment – gandusha (gargling), dhuma (use of medicated smoke), rukshabhojana and vamana(induced emesis after food of dry quality), vyayama(exercise), raktamokshana (blood letting), birechana (purgation), kshara-lavanamishrita taila abhyanga(massage of oil mixed with alkali and salt).[100]

(13) SUKRAVEGARODHA (suppression of urge of semen – sexual urge)– sukrasravana(ejaculation), guhya Vedana(pain in the penis and scrotum), swayathu(swelling -in the scrotum), jwara(rise of temperature), hridvyatha(pain in the heart region), mutrasanga(retention of urine), angabhanga(breaking pain of the body), vriddhi(hernia), adhyashma (calculi), sandhata(impotency).[101]

Treatrment - tamrachuda (eating chicken), sura(wine), shali anna(rice prepared from unboiled crop), basti(enema), abhyanga(massage), avagahana(tub bath), bastishuddhikara aushadha(medicines for cleaning of the urinary bladder) (dieuretics), kshirapana(taking milk), Priya stree sevana(sexual act with beloved female).[102]

Suppressible Natural Urges (Dharaniya Vega)

CHARAKA - The great scholar, father of Indian Medicine (Kayachikitsa), mentions a group of natural urges that are to be suppressed with all efforts to remain free from different types of diseases as follows -

(1) SAHASA – It indicates and means doing anything exceeding one's own strength.[103]

(2) ASHASTA MANOKARMA (improper/avoidable/unethical mental activities) – lobha(lust), shoka(grief), bhaya(fear), krodha(anger), mana(ego), nairlajya(shamelessness), irsha(jelousy), atiraga(excessive attraction), abhidhya (temptation to get other's belongings).[104]

(3) ASHASTA BANI (improper/unethical/harmful speech)– parusha(harsh), atimatra(excessive), suchaka(like an expert), anrita(untruth), akalayukta(that is not suitable for the time).[105]

(4) ASHASTA KAYAKARMA (improper physical activities) – parapidakaraka kriya(anything that can cause suffering of the others), streebhoga (making physical relation with females), asteya [theft], himsa(causing harm to the others).[106]

Ashtangahridaya

In Ashtangahridaya the names of the suppressible natural urges are mentioned as follows -

Lobha (lust), irsha(jelousy), dwesha(enmity), matsarya (miserliness – being incapable of enjoying one's own possessions), raga(attraction).[107]

Discussion

On the observations of the study the following points can be considered as valuable–

(1) The study reflects the minuteness of observations of the ancient Ayurvedic scholars. Interestingly the three scholars have identified the sole aetiology of all diseases as suppression of natural urges. Among the natural urges discussed all are indicative of need of expulsion of some unwanted substances produced during the natural procedure of metabolism and some indicate state of deficiencies fulfilment of which is needed to maintain a healthy state.

Adhovata, purisha, mutra, bomi, eructation indicates the physiological need of excretion/elimination. These excreta (unwanted substances), if not allowed to get expelled out at proper time may cause some untoward effects. The modern observation also says that, if one holds the urge of stool then it may lead to constipation, impaction, inflammation, distension of the rectum, sometimes faecal incontinence, haemorrhoids etc. Holding of the urge of flatus can cause bloating, pain, discomfort, indigestion, heartburn etc. Holding of the natural urge of urination may cause urinary tract infection, pain, bladder stretching, stress on the kidneys even damage, control problem, weakness of pelvic floor muscles etc. Emesis (vomiting) is another situation when the body wants to expel out unwanted (rejectable) substances from the body through mouth. Hence the descriptions of the Ayurvedic scholars in relation to the suppression of these urges can be considered as scientific and practical. Suppression of the urge of eructation makes a person feel miserable, may cause abdominal pain and bloating.Detail description on suppression of these urges are not available in modern classics.

(2) Yawning is an unlearned response to high levels of blood carbon dioxide. Concepts are there saying that, yawning is triggered by an increase in brain temperature and the physiological reactions following a yawn promote a return to brain thermal homeostasis. If one will not yawn taking a deep breath would become harder and harder which is not good for health. Sneez protect the body by clearing the nose from bacteria, virus, foreign body etc. Entry of any unwanted substance in the nose the sneez centre in the brain signals and closes the throat, eyes and mouth. The chest muscles vigorously contract the throat muscles. If one suppresses the urge of sneeze may cause rupture of eardrums, irritation of the throat, rupture of blood vessels in the eyes or brain. These concepts have close relationship with the Ayurvedic descriptions mentioned in the observation heading.

(3) Lacrimation is a process of producing excess tears at the states like emotion, laugh, cough, vomiting, experiencing strong taste sensations, yawning, grief etc. The lacrimal nerve is responsible for lacrimation. At the situations of exposure to unwanted substances, smoke, gas, sand etc. also lacrimation occurs. Resisting the urge to cry can cause trouble like irritability, anxiety, disturbed sleep, cardiovascular diseases (hypertension etc). In common conditions of lacrimation due to exposure to irritants can cause eye diseases. The Ayurvedic concept on this point can be easily justified with this modern understanding.

(4) Sexual urge in men manifests due to some influence of a group of hormones which ends in the form of ejaculation. If one suppresses sexual urge there

may be feeling of frustration, sadness, dissatisfaction etc. Ayurvedic scholars observed on the condition and nicely described the signs and symptoms of suppression with effective treatment.

(5) Hunger indicates emptying of the stomach. It indicates the need of food to the body. At the state of hunger there is deficiency of glucose specially in the brain. Neglecting hunger one can suffer from low blood sugar showing the signs like tiredness, dizziness, sluggishness, shakiness, lack of concentration etc. The description of the Ayurvedic classics on this condition is also praisable as it has close similarity with the modern observations.

(6) Thirst indicates deficiency of fluid in the body. Not taking water/fluid at a state of thirst can cause fatigue and loss of energy initially and in due course it may lead to some serious conditions. It is observed that, the Ayurvedic scholars were aware of these conditions and took step to create awareness among the physicians specially.

(7) On the condition of suppression of increased breathing after exercise the modern observations give same view with the Ayurvedic scholars as “when one performs exercise the body uses more Oxygen and produces more carbon dioxide. To meet this situation the respiratory rate increases and tries to increase the air intake even upto 100 litres per minute which is at rest 12 litre per minute”. If this physiological phenomena is suppressed then definitely the heart and lungs will suffer affecting the health.

(8) Sleep boosts brain power, improves weight management, reduces stress and inflammation. It regulates the functions of the endocrine secretion, body and brain. One when neglects the urge of sleep may develop hypertension, hyperlipidemia, sleep disorders, depression, anxiety, lowering of sex drive, weakness of immune system, problem in thinking and decision making etc. and the risk of diabetes, cancer etc. also increases. These conditions are highly supportive of the Ayurvedic concepts on the situation of not sleeping properly at proper time.

(9) The discussion on Dharaniya Vega seemed to be the contribution of Charaka followed by Bagbhata. It includes the activities related to speech, thinking and physical activities that, if allowed to fulfil, cause loss of respect, name and fame of the individual concern and also cause fear, suspicion, quarrel, disharmony etc. in the society. The effects of speaking more, untruth, like an expert without proper knowledge, harshly, making physical relation with female who is not one’s own wife, theft, jealousy etc. are self explanatory.

Summary

The result of the study can be summarised as follows –

(1) The concept of the "Adharaniya Vega" can be considered as an unique concept of the Ayurvedic classics. Charaka, Susruta and Bagbhata discussed on the topic vividly with priority.

(2) "Adharaniya Vega", as discussed by the 3 Ayurvedic scholars can be nicely justified with modern physiological concepts. The diseases (signs and symptoms) arising due to suppression of the natural urges, like stool, urine, flatus, yawning, sneezing etc. are easily justifiable considering their physiology.

(3) Suppression of the natural urges, if continued for a long duration, can make a person chronically ill and incurable. If the suppression is done in some situations only it can be treated and cured by following Ayurvedic principles.

(4) In most of the situations it is observed that, individuals habitually suppress the natural urges due to some demand of the situation and consult a physician at a state of chronicity and incurability.

(5) Non suppression of the natural urges should be considered as the key of health and nobody should suppress them.

(6) The knowledge of suppressible natural urges mentioned in the Ayurvedic classics are also have importance in personal as well as in social health as non suppression of them ultimately affects the social peace, harmony and discipline.

(7) The descriptions of signs and symptoms of suppression of non suppressible natural urges, their treatment and the concept of suppressible natural urges can be considered as unique that have scope of study, analysis and research.

Conclusion

To conclude it can be said that, every individual should get the knowledge of the Adharaniya and Dharaniya Vega mentioned in the Ayurvedic classics and maintain himself/herself disease free and also should contribute in maintenance of social peace, harmony and discipline.

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7

A Review on Prospects of Nanomaterials in the Removal of Heavy Metals

[1*]Dr. S. Sujatha, [2]Dr. S. Packialakshmi, [3]Dr. T. Udaya Banu, [4]Dr. Senthilkumar Veerasamy, [5]Dr. R. Sivarethinamohan

[1]Professor, K. Ramakrishnan College of Technology, Tiruchirapalli, Tamilnadu, India

[2]Associate Professor, Department of Civil Engineering, Sathyabama Institute of Science and Technology, Tamilnadu, India

[3]Associate Professor, Department of Civil Engineering, Kings Engineering College, Irrungattukottai, Sriperumbudur, Chennai, Tamilnadu, India

[4]Professor, M. Kumarasamy College of Engineering, Karur, Tamilnadu,India

[5]Associate Professor, Symbiosis Centre for Management Studies, Bengaluru (Constituent of Symbiosis International Deemed University), Karnataka, India

*sujalalit@gmail.com

1. Introduction

Any metallic chemical element that is dangerous or poisonous at low concentrations and has a comparatively high density is referred to as a heavy metal. Mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Tl), and lead (Pb) are a few examples of heavy metals.

Some heavy metals display adverse health effects on living organisms and ecosystems when the concentration in the environment exceeds prescribed limit. They bioaccumulate in the food chain and end up in wastewater, calling for advanced techniques of remediation. Here, we review recently developed nanomaterials used to remove heavy metals in wastewater, with focus on synthesis, removal mechanisms and kinetics. Nanomaterial-based adsorbents include zero-valent, carbon-based nanomaterials and nanocomposites. Nanomaterial synthesis is done by co-precipitation, sol–gel, spinning, chemical vapour deposition, pyrolysis and sputtering. Removal mechanisms include chemical precipitation, adsorption, ion exchange, coagulation and membrane filtration.

2. Reasons behind the Significant Usage of Nanomaterials in Adsorption

Nano materials have gained significant attention in the field of adsorption due to their unique properties and high surface area-to-volume ratio, which make them highly effective for adsorbing various substances. Adsorption is the process where molecules or particles adhere to the surface of a solid material. Nanostructured materials offer several advantages for adsorption applications such as High Surface Area,Tailored Properties, Rapid Adsorption Kinetics and Regeneration.

Nano materials possess a large surface area per unit mass or volume, providing more active sites for adsorption compared to bulk materials. This characteristic enhances their adsorption capacity for gases, liquids, or contaminants. The properties of nano materials can be tailored or modified to optimize adsorption by adjusting their size, shape, surface chemistry, and pore structure. This tunability allows for selective adsorption of specific molecules or contaminants. Nanostructured materials often exhibit faster adsorption kinetics due to their smaller size and higher surface reactivity, leading to quicker removal of contaminants from the solution. Some nano materials offer the possibility of regeneration and reuse, which can be advantageous in terms of sustainability and cost-effectiveness for adsorption processes.

3. Nanotechnology that is Applied Upon the Generation of Nano Particles

The nanotechnology techniques could be segregated into wet, dry, and computational engineering. Wet nanotechnology deals with the processes taking place in aqua-environments mostly exploiting living systems and components present in the cell, tissue, and organs of living organisms. Dry engineering handles synthesis of inorganic rigid structures and parts with the help of physicochemical methods, whereas computational nanotechnology concerns with the development and use of computer-based quantum and molecular design, modelling, and simulation of the behaviour or properties of systems relevant to nanotechnology.

4. Kinds of Nanomaterials

Research in nano materials for adsorption continues to evolve, focusing on improving adsorption efficiency, selectivity, and scalability for diverse applications such as wastewater treatment, environmental remediation, gas separation, and purification processes. Several types of nano materials are utilized for adsorption purposes has been discussed in the below content.

Table 1: Nanotechology

1	*2*	*3*	*4*	*5*	*6*	*7*
Physical (Gas solid transformation)	***Chemical (Liquid solid transformation)***	***Biological (Bioreduction)***				
• CVD and PVD • Spray pyrolysis • ion implementation	• co-precipitation • sol-gel • chemical reduction • sono and photo chemical	• by plants • by bacteria • by fungi • by yeast	• bulk nanomaterial • fragmentation • lithography	• Biomimetic and tissue nanotechnology • Bioimaging. biosensing and bioanalytics	• information and processing • electronics and photonics	Quantum or molecular mechanism

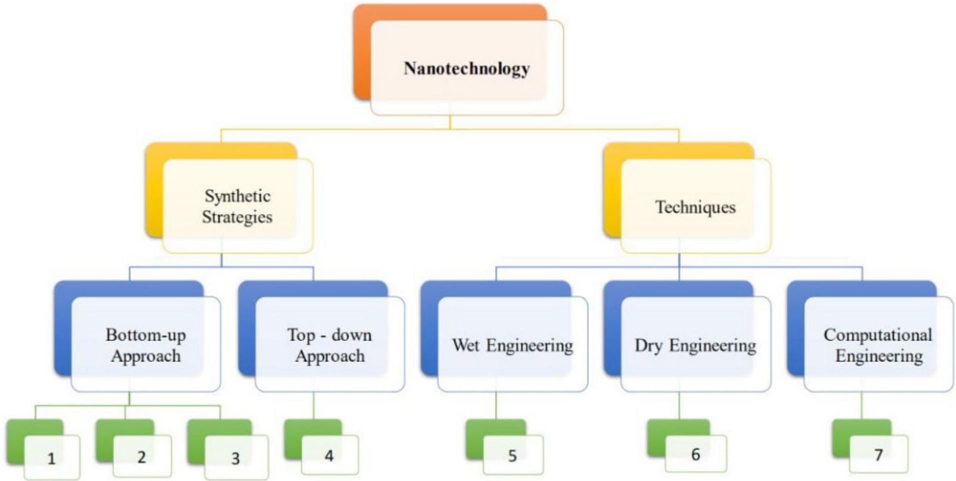

Fig. 1: Nanotechnology techniques

4.1 Carbon-Based Nano-materials

Carbon nanomaterials are an extensive family of carbon allotropes, consisting of 0-dimensional fullerenes and quantum dots, 1-dimensional carbon nanotubes (CNTs), 2-dimensional graphene, and 3-dimensional nanodiamonds and nanohorns. Graphene, carbon nanotubes (CNTs), activated carbon nanoparticles, and carbon nanofibers are widely used due to their high surface area and excellent adsorption capabilities for various pollutants, organic compounds, heavy metals, and gases.

4.2 Metal and Metal Oxide Nano-materials

Several metals oxides have been extensively investigated for lead adsorption, including manganese, aluminum, iron, and so on. These materials have been employed for heavy metal removal due to their low toxicity. Metal nanoparticles

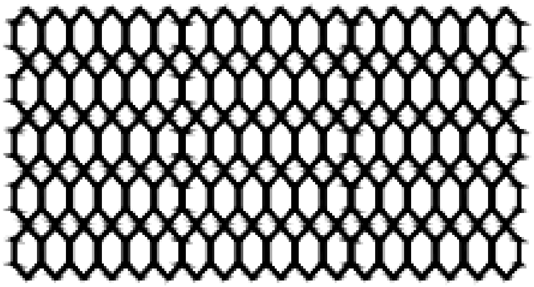

Fig. 2: Graphene

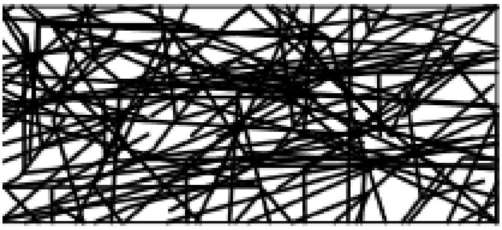

Fig. 3: Nanocomposites

(e.g., silver, gold, iron) and metal oxide nanoparticles (e.g., titanium dioxide, iron oxide) have shown promise in adsorbing contaminants, acting either as adsorbents themselves or as catalysts in adsorption processes.

4.3 Metal-Organic Frameworks (MOFs)

MOFs are crystalline materials composed of metal ions or clusters connected by organic linkers. Their tunable pore sizes and high surface areas make them excellent candidates for adsorption applications, including gas storage, separation, and pollutant removal. These are composed of metal ions or clusters linked by organic ligands, forming highly porous structures. MOFs exhibit tunable pore sizes and exceptional surface areas, ideal for selective adsorption of gases and molecules.

4.4 Nanocomposites

Combinations of different nano materials or nanostructured composites (e.g., polymer-based nanocomposites, hybrid materials) are designed to synergistically enhance adsorption capacities and selectivity.

4.5 Activated Carbon Nanomaterials

ACNPs are processed carbonaceous materials with uniform surface morphology, excellent biocompatibility, abundant pores having high surface area and chemical reactivity, mechanical strength and stability. Nano-sized activated carbon materials possess a high surface area and porosity, making them excellent for adsorbing gases, organic compounds, and pollutants from air and water.

4.6 Nanoporous Silica

Silica-based nanoparticles with controlled pore sizes are effective in adsorbing various substances, including organic pollutants and heavy metals from water.

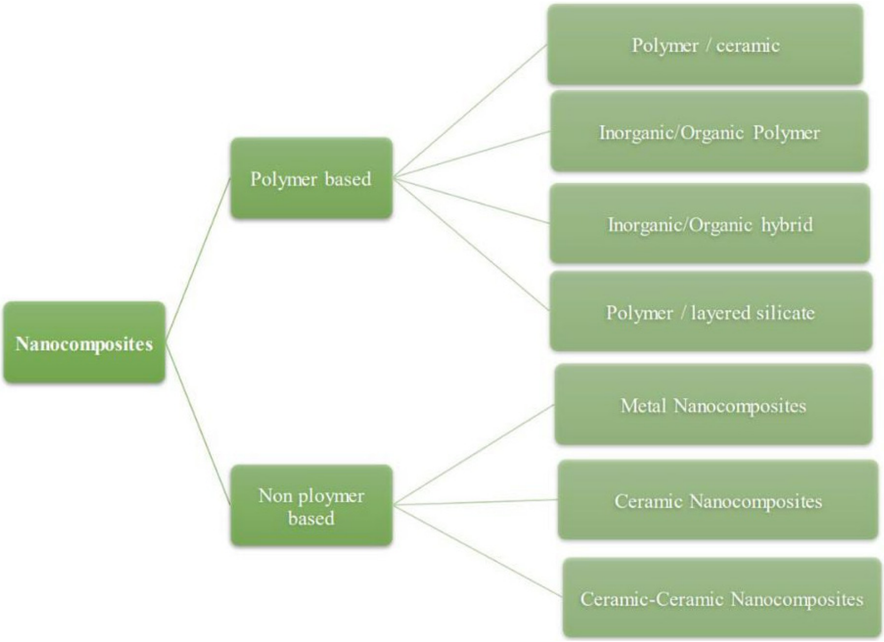

Fig. 4: Nanocomposites

The advantages of using nanomaterials for adsorption include their high efficiency, large surface area, tunable properties, and the ability to modify their surfaces for specific adsorption requirements. However, challenges like scalability, cost-effectiveness, and potential environmental impacts need consideration for practical applications.

5. Conclusion

Researchers are continually exploring novel nanomaterials, surface modifications, and fabrication techniques to enhance adsorption capacities and selectivity for various pollutants, making nanotechnology an exciting field in environmental remediation and purification processes. Adsorption using nano materials has shown a promising results in removing the heavy metals from the wastewater.

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8

Influence of Coating on Reinforcements on Mechanical Properties and Wear Behaviour of Metal Matrix Composites—A Review

Dr. K.A.Emmanuel

Professor, Department of Chemistry, Y.V.N.R. Government Degree College, Kaikaluru, Eluru District-521333. Andhra Pradesh.

ABSTRACT

Composite materials have been widely used in various applications because of its higher mechanical properties and wear resistance while compared to matrix. The desirable properties can be achieved by reinforcing particles, fibers and whiskers in aluminium alloy. However, the composite material fails when its subjected to loading. It is due to poor interface bonding between matrix and reinforcement. The bonding between matrix and reinforcement can be improved by suitable coating on reinforcements. Coated reinforced composites offering better mechanical properties and wear resistance when compared to uncoated reinforced composites and monolithic alloy.

Keywords: Aluminium alloy, Coating, Mechanical Properties, Wear.

1. Introduction

Many researchers have investigated the mechanical properties and wear behaviour coated reinforced composites and compared the results with monolithic alloy. The researchers reported that the formation of intermetallic compounds can be prevented by applying suitable coatings on reinforcement.[1-3]

Ganesh et al.[1] investigated the mechanical properties of AA1050 aluminium alloy reinforced with galvanized iron wires. 2.5 vol% of zinc coated galvanised iron wires with 0.8 mm diameter were reinforced in aluminium produced by casting process followed by hot extrusion. The results revealed that composites exhibited better mechanical properties over monolithic alloy. Micrographs of composite revealed that good interface bonding between aluminium and iron wires. Reinforcement of zinc coated galvanised iron wires in aluminium increased the density, percentage of porosity, hardness, elastic modulus, yield strength and tensile strength. However, ductility and coefficient of thermal expansion decreased with increasing vol% of galvanized wires reinforcement.

Ganesh et al.[2] experimented AA1050 aluminium alloy reinforced with zinc coated galvanized iron wires preform produced by melt deposition technique followed by hot extrusion process. 0.8vol% of galvanized iron wires with 1.2 mm diameter were reinforced aluminium alloy. Addition of reinforcements improved the mechanical properties of composites compared to monolithic alloy. Micrographs of composite showed good interface bonding between wires and reinforcement with minimal pores at the interface. Composite exhibited superior mechanical properties compared to matrix. However ductility and coefficient of thermal expansion decreased with increasing vol% of reinforcement. Fracture surface of matrix showed the presence of dimples resulted ductile fracture. Crack was initiated at the interface of matrix/reinforcement which propagated resulted in fracture of composites. Wire pull out, dimples and broken wires were observed while examined the fracture surface of composites.

Tekmen&Cocen[3] investigated the microstructure and mechanical properties of LM25 aluminium alloy reinforced with nickel coated silicon carbide (SiC) particles fabricated using squeeze casting process. 20vol% of silicon carbide with average particles size of 15 µm was coated using electroless technique, added to the melt and the composite melt was solidified under the squeeze pressure of 100 MPa. Micrograph of composites revealed homogeneous and uniform distribution of particles in matrix. Porosity of composite increased with in increasing wt% of reinforcement and application of squeeze pressure reduced the amount of porosity and shrinkages. Presence of nickel as coating on reinforcement acted as protective layer between matrix and reinforcement and prevented the formation of Al_4C_3. Reinforcement of SiC particles in aluminium alloy significantly improved ultimate tensile strength, yield strength with reduction in ductility. Fracture surface of composites revealed fracture of silicon particles and ductile fracture was observed during tensile test.

Mandal et al.[4] studied the mechanical properties of copper, nickel and uncoated short steel fibers reinforcement in aluminium produced by stir casting process. Electroless deposition method was used to coat the reinforcement. 500 – 800 µm length and 80 – 120 µm diameter of steel fibers were used as reinforcement and 5wt% of steel fibers were reinforced in aluminium. The results revealed that addition of steel fibers significantly improved the mechanical properties of composites compared to matrix. Density, hardness, yield strength and ultimate tensile strength of composite increased with reinforcement of steel fibers in matrix. However, addition of steel fibers decreased the ductility and increased the percentage of porosity in castings. Copper coated steel fiber reinforced composites showed better mechanical properties over aluminium, aluminium reinforced with nickel and uncoated steel fibers. Fracture surface of matrix showed dimple formation resulted in ductile fracture and fiber pull out with dimples were observed in composites. Copper coated steel fiber reinforced composite showed dimples on the surface and coalesced rather than fiber pull out. This was attributed to the better interface bonding between matrix and reinforcement.

Mandal et al.[5] studied the effect of uncoated, copper and nickel coated short steel fibers reinforcement in aluminium processed using stir casting process. Short steel fibers of 120 μm in diameter and 350–550 μm in length were coated using electroless technique and 5wt% of fibers were reinforced in aluminium. Dry sliding wear test was carried out by varying load range from 10 – 40 N with sliding velocity of 1.8 m/s for a constant sliding distance of 2000 m. Addition of steel fibers significantly improved the hardness, tensile strength, yield strength and wear rate of composites. Copper coated steel fiber reinforced composites exhibited maximum hardness, tensile strength and yield strength compared to uncoated and nickel coated short steel fiber composites. However ductility of composites decreased by the addition of reinforcement in matrix. Micrographs of copper coated steel fiber reinforced composites showed good interface bonding between matrix and reinforcement. Cumulative volume loss of matrix and composites increased with increasing load and sliding distance and decreased with addition of fibers in matrix. Copper coated steel fiber reinforced composites exhibited better wear resistance over uncoated and nickel coated steel fiber reinforced composites. Wear rate and coefficient of friction decreased with increasing sliding distance and reinforcement of fibers. However, wear rate and coefficient of friction increased with increasing load. A regression equation was developed to predict the wear rate of composites. Delamination was predominant and long continuous grooves were observed in matrix. Worn surface of composites showed fine grooves due to ploughing rather than delamination. Worn surface of copper coated steel fiber reinforced composites showed fine grooves on the surface parallel to the sliding direction and width of the grooves were minimum in size compared to uncoated and nickel coated fiber reinforced composites.

Mandal et al.[6] discussed the effect of copper and nickel coating on short steel fibers reinforcement in aluminium – magnesium alloy (Al - Mg) processed through stir casting process. 5wt% steel fibers of 85 - 120 μm diameter and 550 - 850 μm length were coated using electroless plating technique, added to the melt and stirred at 500 – 750 rpm. 2wt% of magnesium was added which improved the wettability of fibers in matrix. The results revealed that reinforcement of steel fibers improved the mechanical properties of composites compared to Al – Mg alloy. Microstructure of composite showed uniform distribution of fibers and better interface bonding was achieved using copper coating on reinforcements. Hardness, density, percentage of porosity, yield strength and ultimate tensile strength of composite increased by the addition of 5 wt% of reinforcement in matrix. Ductility of composite decreased with reinforcement of hard steel fibers in matrix. Copper coated steel fiber reinforced composite exhibited superior mechanical properties compared to uncoated and nickel coated steel fiber reinforced composites. Fracture surface of matrix showed dimples on the surface and fiber pull out was observed in uncoated and nickel coated steel fiber reinforced composites. Fracture surface of copper coated steel fiber composite revealed dimple formation with coalesced rather than fiber pull out.

Mandal et al.[7] investigated the effect of copper coated steel fibers reinforcement in aluminium fabricated using stir casting process. Short steel fibers of 120 µm diameter and 450 – 550 lm length were coated using electroless process and wt% of reinforcement varied from 0 to 10. Dry sliding wear test was performed by considering load varied from 10 to 40N, with constant velocity of 1.85 m/s for a sliding distance of 2000 m. The results revealed that reinforcement of copper coated steel fibers significantly improved the mechanical and wear properties of composites compared to monolithic aluminium. Presence of copper as coating improved the wetting behaviour resulted better interface bonding between matrix and reinforcement. Micrographs of composites showed better distribution of fibers in matrix. Density, percentage of porosity and hardness of composites increased with increasing wt% of copper coated steel fibers in matrix. Tensile strength of composite increased with increasing weight fraction of reinforcement up to 5% and further addition of reinforcement decreased the tensile strength. 10wt% of composite decreased the wear rate up to 40% while compared to matrix. Cumulative volume loss decreased with increasing wt% of reinforcement and increased with increasing sliding distance and load. Wear rate and coefficient of friction decreased with increasing sliding distance and wt% of reinforcement. Regression equation was developed to predict the wear rate of composites. Worn surface of matrix showed extensive long continuous parallel to the sliding direction. Smooth and fine grooves were observed for composites at lower loads and extensive surface ploughing, local delamination were observed at higher loads. Adhesive wear was observed for monolithic aluminium and composite with 5wt% reinforcement. However abrasive wear was observed for 10wt% reinforced composites.

Mandal et al.[8] discussed the effect of coating on short steel fiber reinforcement in aluminium – magnesium alloy (Al – Mg) processed using stir casting. Steel fibers of 550 – 850 µm average length and 85 -120 µm average diameter were used as reinforcement. Copper and nickel coating on fibers was carried out using electroless plating method. 5wt% of steel fibers were added to the melt and stirred at 500 - 750 rpm while processing composites. Wear test was performed by varying load such as 10, 20, 30 and 40 N with 1.85 m/s velocity and a constant sliding distance of 2000 m. The results revealed that reinforcement of steel fibers significantly improved the wear resistance of composites compared to monolithic aluminium. Microstructure of copper coated composites showed uniform distribution of fibers throughout the matrix and better interface bonding was achieved using copper coating on fibers. Dry sliding wear test results revealed that wear rate of composites decreased with increasing sliding distance and load. Coefficient of friction increased with increasing load and decreased with increasing sliding distance. Delamination was predominant in matrix and fine grooves were observed in composites. Width of the grooves and size of dimples were increased with increasing load from 10 to 40 N. Composite showed extensive surface ploughing with local delamination while examined the worn surface at 40 N load. Copper coated steel fiber reinforced composites exhibited superior wear resistance over aluminium alloy, uncoated and nickel coated steel fiber reinforced composites.

Mandal et al.[9] investigated the effect of copper and nickel coating on short steel fiber reinforcement in aluminium and Al – Mg alloy fabricated using stir casting process. 5wt% steel fibers of 550 - 850 µm in length and average diameter of 80 - 120 µm were coated using electroless technique. Micrograph of composite showed uniform distribution of fibers throughout the matrix and good interface bonding was achieved using copper coating on reinforcements. Addition of magnesium improved the wettability resulted homogeneous distribution of fibers in matrix. Copper coating on steel fiber reinforced composites exhibited better hardness over nickel coated and uncoated steel fiber reinforced composites. Maximum hardness was observed at the top and bottom of the cast sample due to the segregation of fibers in matrix.

Mandal et al.[10] discussed the effect of wt% reinforcement of copper coated steel fibers in aluminium – magnesium alloy (Al – Mg) fabricated using liquid process vortex method. Steel fibers of 80 – 120 µm diameter and 500 – 800 µm length were copper coated using electroless deposition method, added to the melt and stirred at 500 – 750 rpm while processing composites. Wt% steel fibers varied from 0 – 10 and 2wt% magnesium was added which promoted the wetting of fibers in matrix. The results revealed that reinforcement of steel fibers significantly improved the mechanical properties of composites compared to matrix. Density, hardness and percentage of porosity increased with increasing wt% of reinforcement. Yield strength, ultimate tensile strength of composites increased with increasing wt% of reinforcement up to 5wt%. Further addition of steel fibers decreased the tensile strength of composites. Maximum tensile strength of 162 MPa was observed for 5wt% copper coated steel fiber reinforced composites. Ductility of composites decreased with increasing wt% of reinforcement. Regression equation was developed to predict the ultimate tensile strength of composites. Fracture surface of matrix showed dimples on the surface which resulted ductile fracture. Fiber pull out was observed in composites and it increased with increasing wt% of reinforcement.

Mandal et al.[11] investigated the dry sliding wear behaviour of copper coated steel fibers reinforcement in aluminium – magnesium alloy (Al – Mg) fabricated using stir casting process. Wt% of reinforcement varied from 0 – 10 and the steel fibers were coated using electroless deposition method. Steel fibers of 550–850 μm average length and 85–120 μm average diameters were reinforced in Al – Mg alloy. Wear test was conducted at room temperature by varying load (10 – 40 N) with constant velocity of 1.85 m/s and a sliding distance of 2000 m. Microstructure of samples showed uniform distribution of fibers in matrix and better interface bonding between matrix/reinforcement. The results revealed that reinforcement of copper coated steel fibers improved the wear resistance of composites when compared to matrix. Cumulative weight loss increased with increasing sliding distance and load and decreased with increasing wt% of reinforcement. Wear rate and coefficient of friction decreased with increasing sliding distance and wt% of reinforcement. A regression equation was developed to predict the wear rate of composites. Microscopic examination of wear debris revealed that size of wear debris decreased with increasing wt% of reinforcement and increased with increasing load. Worn surface of matrix showed long continuous grooves parallel to the sliding direction and local delamination was observed. Smooth and fine grooves were observed for composites and width of the grooves increased with increasing load.

Hajjari et al.[12] investigated the effect of nickel coating on carbon fibers reinforcement in 2024 aluminium alloy fabricated using squeeze casting. Carbon fibers of 5.7 μm in diameter coated with nickel using electroless method. 40vol% of carbon fiber infiltrated in aluminium and squeeze pressure varied from 30 – 70 MPa while producing composites. Micrographs of uncoated carbon fiber reinforced composite showed incomplete filtration and nickel coated carbon fiber reinforced composite showed better interface bonding between aluminium and carbon fiber. Nickel coating on fibers improved the wettability of carbon fiber with aluminium and offered better interface bonding between fiber and matrix. Squeeze pressure of 30 – 50 MPa was found as optimum squeeze pressure for the reinforcement of nickel coated and uncoated carbon fiber reinforced composites.

Urena et al.[13] investigated the dry sliding wear behaviour of AA 6061 aluminium alloy reinforced with silica coated silicon carbide (SiC) particles and copper/nickel coated carbon fibers produced by stir casting process. SiC with average particle size of 26 μm was coated using sol – gel technique and carbon fibers with average diameter of 7.2 μm were coated by electroless process. Composite was produced by considering 20wt% of SiC and 2wt% of carbon fibers. Metallic coating on fibers improved the wetting behaviour while processing, dissolved in aluminium and prevented the formation of intermetallic compounds. Micrograph of composites showed uniform distribution of reinforcement throughout the matrix. Reinforcement of SiC particles and C fibers in aluminium improved the hardness and wear resistance of composites compared to monolithic aluminium alloy. Copper coated carbon fiber reinforced composites exhibited superior hardness and wear resistance over nickel coated carbon reinforced composites. Al – SiC - C reinforced composite resulted better wear resistance over Al - SiC reinforced composites due to the reinforcement of secondary reinforcement as carbon fibers in aluminium.

Hajjari et al.[14] discussed the effect of nickel coating on carbon fiber reinforcement in 2024 aluminium alloy fabricated using squeeze casting process. Carbon fibers with average diameter of 5.7 μm were coated using electroless method. Squeeze pressure varied from 30 to 70 MPa and 20wt% of fiber was reinforced in aluminium alloy. The results revealed that addition of carbon fibers improved the tensile strength of composites while compared to 2024 aluminium alloy. Nickel coating on fibers protected the fiber against reaction with aluminium and improved the wettability while processing the composites. Micrograph of composite confirmed better interface bonding between carbon fibers and aluminium alloy due to the presence of nickel as coating on fibers. Application of high squeeze pressure separated the nickel coating and damaged the distribution of fibers in matrix which decreased the tensile strength of composites. Maximum tensile strength was observed for the composite fabricated with squeeze pressure of 30 MPa. Fracture surface of composite showed fiber pull out and cracks were initiated at the interface of aluminium and carbon fibers resulted failure of composite.

Ivanus[15] reported the effect of copper coating on silicon carbide (SiC) particles reinforced in copper alloy fabricated using powder metallurgy technique. SiC particles with average diameter of 20 μm were copper coated using electroless plating technique and vol% of reinforcement varied from 5 – 20. The results revealed that addition of silicon carbide particles improved the mechanical properties and wear resistance of composites compared to monolithic copper alloy. Copper coating on reinforcement resulted better interface bonding between matrix and reinforcement. Hardness and tensile strength of composites increased with increasing volume fraction of reinforcement up to 10%. Further addition of reinforcement reduced the mechanical properties of composites. Copper coated SiC reinforced composites exhibited superior mechanical and wear resistance over uncoated SiC reinforced composite and matrix.

Urena et al.[16] discussed the effect of copper coating on short carbon fibers reinforcement in AA 6061 aluminium alloy produced using liquid and semi liquid processing techniques. Carbon fibers with average diameter of 7.28 µm were coated using electroless coating technique and 3vol% of fibers was reinforced in aluminium alloy. The results showed that copper coating on fibers prevented the formation of intermetallic compound between aluminium and carbon fibers. Microstructure of castings showed uniform dispersion of carbon fibers throughout the matrix and wettability promoted better interface bonding between matrix and reinforcement. Hardness of composites increased with addition of carbon fibers and copper coated carbon fiber reinforced composites exhibited superior hardness over uncoated carbon fiber reinforced composites and monolithic aluminium alloy.

Singh &Balasubramanian[17] investigated the reinforcement of copper coated carbon fibers in 6061 aluminium alloy processed through stir casting process. Carbon fibers of 4 - 8 mm length and 6 µm in diameter were coated using electroless technique. Wt% of reinforcement varied from 1 to 6 and reinforced with aluminium alloy in a semi-solid state while processing the composites. Microstructure of composites showed uniform distribution of fibers throughout the matrix and better interface bonding between matrix/reinforcements with micro porosities in castings. Reinforcement of carbon fibers improved the mechanical properties of composites compared to monolithic aluminium alloy. Hardness of composites increased with increasing wt% of reinforcement and maximum hardness was observed at 1wt% of carbon fiber reinforced composites. Ultimate tensile strength and yield strength of composites increased with increasing wt% of fibers up to 4wt%. Further addition of fibers reduced the tensile strength due to the presence of more amounts of voids at the interface of carbon fiber and aluminium alloy. However ductility of composites decreased with increasing wt% of reinforcement in matrix.

Ramesh et al.[18] reported the mechanical properties of Ni - P coated silicon nitride (Si_3N_4) particles reinforcement in 6061 aluminium alloy fabricated using stir casting process. Si_3N_4 particles with average diameter of 2 – 10 µm were coated using electroless technique and wt% of reinforcement varied from 0 – 10. Microstructure of composites showed uniform dispersion of particles throughout the matrix. Ni - P coating on reinforcement improved wettability resulted better interface bonding between matrix and reinforcement. Addition of reinforcements improved the mechanical properties of composites compared to monolithic aluminium alloy. Hardness and tensile strength of composites increased with increasing wt% of reinforcement and maximum hardness and tensile strength were observed for 10wt% silicon nitride particles reinforced composites. Fracture surface of matrix showed dimples on the surface resulted ductile fracture during tensile test. In contrast, cracks were initiated at the interface of matrix/reinforcement, deboned particles from matrix and fracture of reinforcement phase were observed in composites.

Tang et al.[19] discussed the effect of various coatings on carbon fiber reinforced 6061 aluminium composites processed by vacuum pressure infiltration method. Ni and Cu coatings were carried out using electroless method. Sol – gel method was used to coat Al_2O_3 on fibers. 10wt% of carbon fiber with average diameter of 7 µm, 2 - 3 mm length was reinforced in aluminium alloy. A pressure of 7 MPa was applied while processing the composites. Coating on fibers improved the wetting of fibers in matrix during processing and copper coating on reinforcement offered better interface bonding between fiber and matrix. Reinforcement of carbon fibers in matrix increased the hardness and tensile strength of composites with reduction in ductility. Copper coating on fiber reinforced composites exhibited better hardness compared to Ni, Al_2O_3 and uncoated fiber reinforced composites. Al_2O_3 coated fiber reinforced composites resulted superior tensile strength compared to other coated fiber reinforced composites and uncoated fiber reinforced composites.

Xia et al.[20] investigated the mechanical and wear properties of copper coated carbon fiber reinforced copper matrix composites fabricated using hot pressing technique. Carbon fibers of 6 µm diameter and 4 – 8 mm length were coated using electroless plating technique. Vol% of carbon fiber was varied from 0 – 20 and sintered at a pressure of 100 MPa. Micrographs of composites showed better interface bonding between matrix and reinforcement and copper coating was uniform and continuous throughout the length of fiber. Addition of reinforcement improved the mechanical properties and wear resistance of composites when compared to matrix. Density, hardness, bending strength of composites increased with increasing wt% of reinforcement and 15vol% of reinforcement offered better mechanical properties compared to other vol% of reinforcement. Friction coefficient decreased by the reinforcement of carbon fibers in matrix. Wear rate of composites decreased with increasing wt% of reinforcement and 10wt% of reinforcement exhibited lower wear rate. Worn surface of matrix showed excessive plastic deformation and adhesive wear was predominant. Adhesive with oxidative wear was predominant in composites and worn surface showed mild grooves compared to matrix.

Ning et al.[21] discussed the effect of nickel coating on titanium carbide (TiC) reinforced stellite 712 composites processed using sintering with hot iso-static pressing. TiC with average particle size of 10 μm was reinforced in stellite and wt% of reinforcement varied from 20 – 50. Microstructure of coated TiC composites showed better interface bonding between matrix and reinforcement. Reinforcement of TiC particles improved the wear resistance of composites compared to matrix. Nickel coated titanium carbide particles improved the ductility and fracture toughness of composites.

Pourhosseini et al.[22] investigated the effect of coatings on mechanical properties of Al – Al_2O_3 composites fabricated using stir casting process. Alumina particles were coated using electroless technique and the effect of Cu, Ni and Co coating were investigated by varying wt% of reinforcement as 1 - 10. Microstructure of composites showed better interface bonding between matrix and reinforcement due to the wetting of coated reinforcements in molten aluminium. Also uniform dispersion of particle was achieved throughout the matrix. The results revealed that addition of alumina particles in matrix improved the mechanical properties of composites compared to monolithic aluminium alloy. Hardness, tensile strength, yield strength and compressive strength of composites increased with increasing wt% of reinforcement with reduction in percentage of elongation. Nickel coated alumina particle reinforced composites exhibited superior mechanical properties over other coated particle reinforced composites and matrix.

Chelladurai et al investigated the mechanical properties and wear behaviour of steel fibers, wires and mesh reinforced aluminium based composites using liquid metallurgy route. Copper and zinc coating on reinforcements offered better interface bonding between matrix and reinforcement.[23-31] The results reveal that coated reinforced composites exhibited better mechanical properties and wear resistance while compared to monolithic alloy.

2. Conclusion

Coating on reinforcements improves the interface bonding between matrix and reinforcement and prevents the formation of intermetallic compounds. Electroless method is cheap and cost effective process to produce coating on reinforcements. Good interface bonding between matrix and reinforcement increased the hardness, tensile strength and wear resistance of composites. Hence the coated reinforced composites can be used in various automotive and aerospace applications.

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9

Investigation on DC Chopper Controlled PMSG Driven Horizontal Axis Wind Turbine

[1]S. Sivaranjani, [2*]K.C. Ramya, [3]S. Sheeba Rani, [4]G. Radhakrishnan

Department of Electrical and Electronics Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, Tamilnadu, India.

*e-mail: ramyakc@skcet.ac.in

1.1 Introduction

The Conventional energy sources such as oil, natural gas, coal and nuclear are finite and generate pollution. In recent years, renewable sources such as solar, wave and wind are used for the generation of electricity. Wind is one of the major renewable sources.[1] The amount of energy from a WECS (Wind Energy Conversion System) depends not only on the wind at the site, but also on the control strategy used for the WECS. In order to achieve optimum wind energy extraction from the WECS, the wind turbine generator (WTG) is operated in variable speed mode. The variable speed capability is achieved through the use of an advanced power electronic converters.[8]

1.2 Generation of Electricity from Wind Energy

Wind power is converted into electricity by a wind turbine. In a typical, modern, large-scale wind turbine, the kinetic energy in the wind (the energy of moving air molecules) is converted to rotational motion by the rotor – typically a three-bladed assembly at the front of the wind turbine. The rotor rotates a shaft which transfers the motion into the nacelle (the large housing at the top of a wind turbine tower). Inside the nacelle, the slowly rotating shaft enters a gearbox that greatly increases the rotational shaft speed. The output (high-speed) shaft is connected to a generator that converts the rotational movement into electricity at medium electrical energy (a few hundred volts).[12] The Power flows through heavy electric cables inside the tower to a transformer, which steps up the voltage to the distribution voltage level (a few thousand volts). The basic components of a wind electric system proposed in this project are as shown in Figure 1.2. Wind Turbine converts wind energy in to rotary mechanical energy. A mechanical interface consists of step up gear and a suitable coupling transmitter, which is connected between wind turbine and Permanent Magnet Synchronous Generator (PMSG). The variable AC voltage from the generator is first converted into DC using an uncontrolled diode bridge rectifier. The voltage across the rectifier terminal is regulated by controlling the duty ratio of DC/DC converter. The available DC power is fed to the load at the required level of voltage and frequency by PWM inverter.[6]

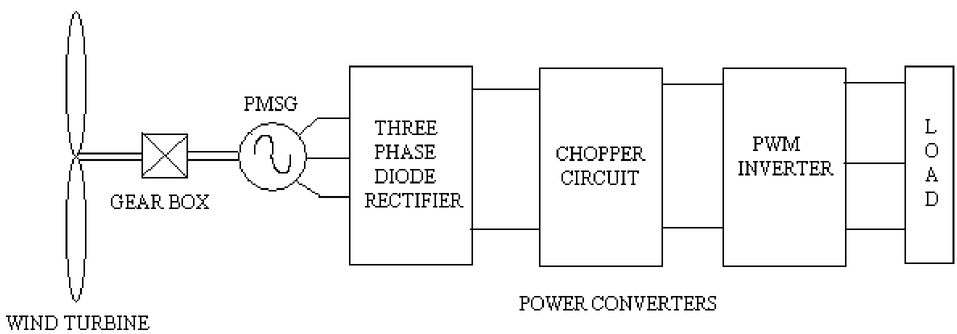

Fig. 1: Basic components of wind electric system

Most of the wind turbine generators use Horizontal axis wind turbine due to the advantages of ease in design and cost effective for higher power ratings. The principal components of a modern wind power plant are the tower, the rotor and the nacelle.

The entire nacelle assembly is placed over the tower through a yaw assembly. Anemometer on the nacelle top is used to measure the wind speed and transmits wind speed data to the controller. The wind vane, which is also located on the top of the nacelle senses the wind direction and communicate with the yaw drive to orient the turbine properly with respect to the wind. Yaw motor powers the yaw drive. The control signal from the controller releases the yaw brakes and the entire nacelle assembly is oriented towards the maximum wind direction.[12]

1.2.1 Power Obtained from the Wind

Wind is merely air in motion. The air has mass, though its density is low. When this mass has velocity the resulting wind has kinetic energy, which is proportional to the product of mass and square of the velocity.[5]

The mass of air passing in unit time is the product of air density (ρ), area swept by the blades (A) and velocity of Wind (V).

The kinetic energy pass through the area $K.E = \rho AV^3$ …(1.1)

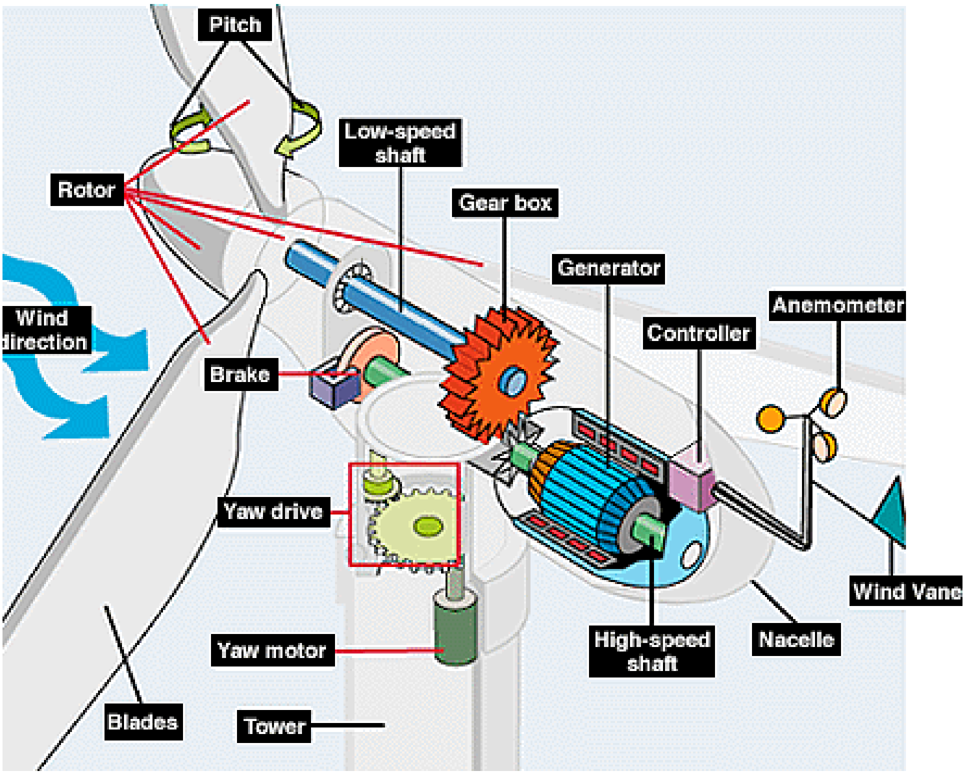

Fig. 2: Horizontal axis wind turbine

1.2.2 Simple Momentum Theory

The retardation of wind passing through a windmill occurs in stages, one before and one after its passage through the windmill rotor. The momentum depends on differences between upwind (V_1) and downwind (V_2).[12]

The rate of change of momentum = $m\,(V_1 - V_2)$ …(1.2)

The power absorbed = $m\,(V_1 - V_2)\,V$ …(1.3)

The rate of change of kinetic energy in wind = $(1/2)\,m\,(V_1^2 - V_2^2)$ …(1.4)

From the equations (1.2) and (1.4)

$$m\,(V_1 - V_2)\,V = (1/2)\,m\,(V_1^2 - V_2^2) \qquad \text{…(1.5)}$$

Thus the retardation of the wind $V_1 - V$ before the rotor is equal to retardation $V - V_2$ behind it.

The power extended by the wind rotor is

$$P = \rho\, AV\,(V_1 - V_2)\,V$$
$$= \rho\, AV^2\,(V_1 - V_2)$$

$$= \rho A (V_1 + V_2/2)^2 (V_1 - V_2)$$

$$= \rho A V_1^3[(1 + \alpha)(1 - \alpha^2)] \qquad \ldots(1.6)$$

Where the angle $\alpha = (V_1/V_2)$

It can be shown that the power as given in equation (1.6) is maximum when $\alpha = 1/3$ and therefore the final wind velocity V_2 is one third of the upwind velocity V_1. The maximum power thus obtained becomes $\rho A V_1^3$ (8/27). An ideal wind turbine could therefore extract 59.3% of the power in the wind.

The simple momentum theory assumes that the air velocity is uniform over the area swept by the blades. The fraction of power extracted is known as power-coefficient (C_p).

1.2.3 Uncontrolled Bridge Rectifier

Rectifiers can be classified as uncontrolled and controlled rectifiers, and the controlled rectifiers can be further divided into semi-controlled and fully-controlled rectifiers. Uncontrolled rectifier circuits are built with diodes, and fully-controlled rectifier circuits are built with SCRs. Both diodes and SCRs are used in semi-controlled rectifier circuits.[11] Power rating of a single-phase rectifier tends to be lower than 10 kW. Three-phase bridge rectifiers are used for delivering higher power output, up to 500 kW at 500 V dc or even more.

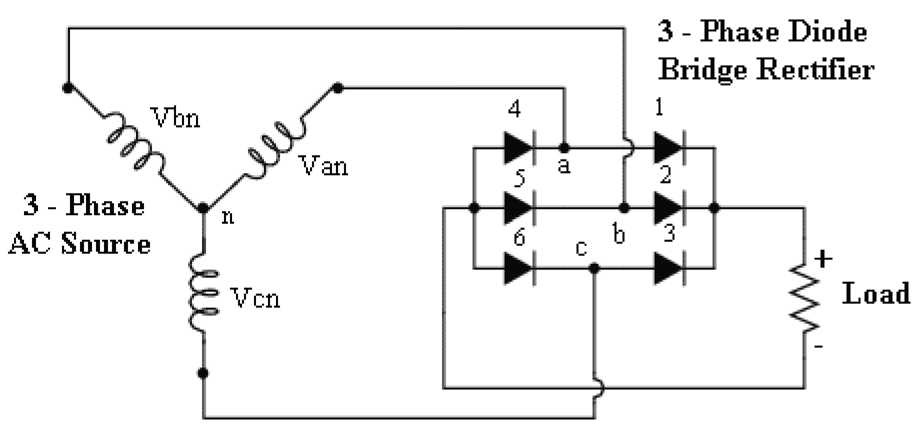

Fig. 3: Three phase uncontrolled bridge rectifier

In each region there are two diodes that are conducting at the same time. One diode provides the path for the current toward the load resistor and other establishes the return path. Diodes 1, 2, and 3 provide the forward path while 4, 5, and 6 provide the return path. Each diode conducts during two conduction regions. Each voltage source carries a current for the 4 conduction regions.

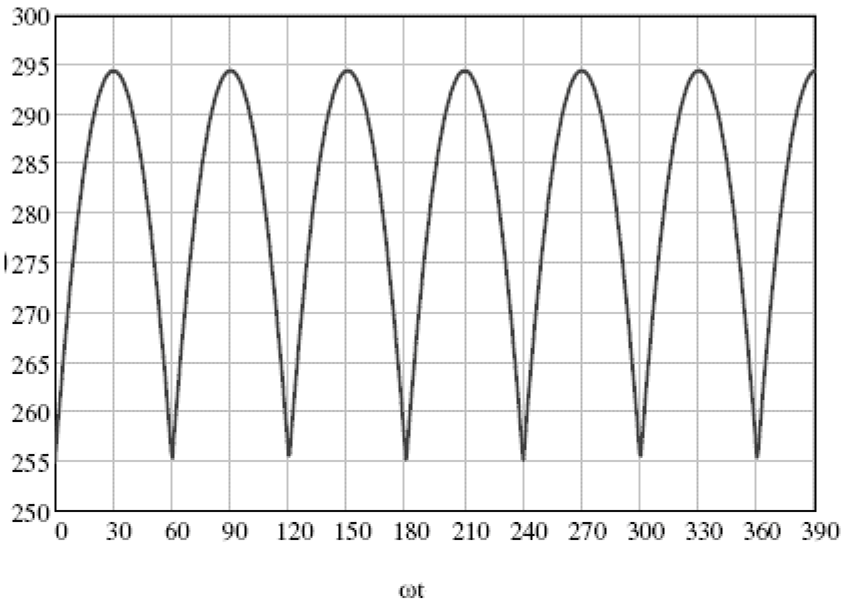

Fig. 4: Output voltage waveform for three phase uncontrolled bridge rectifier

1.2.3.1 Theoretical Analysis[11]

When $60 \le wt \le 120$, V_{ab} supplies power to Load via 1 and 5

Average output voltage $V_{dc} = \dfrac{6}{2\pi}\int_{60}^{120} Vm \sin wt dwt$ …(1.9)

Upon integration, the above equation yields,

$$V_{dc} = \frac{3\ Vm}{\pi} \quad \text{…(1.10)}$$

Average load current Idc = $\dfrac{Vdc}{R_L}$ …(1.11)

The rms output voltage V_{rms}= $\sqrt{\dfrac{6}{2\pi}\int_{60}^{120}(Vm \sin wt)^2 dwt}$ …(1.12)

When integrated the above equation, it yields

Rms output voltage across load V_{rms} = 0.955 Vm …(1.13)

Rms value of load current $I_{rms} = \dfrac{V_{rms}}{R_L}$ …(1.14)

1.2.4 Step Up Chopper

The conversion of fixed DC voltage to an adjustable DC output voltage, through the use of semiconductor devices, can be carried out by the use of DC – DC converters or chopper circuits. As stated above, a chopper is DC equivalent to an AC transformer having continuously variable turns ratio. In Wind Electric Conversion Systems, step up chopper is used to boost up the voltage from the three phase diode bridge rectifier. During this Ton time period inductor stores energy. When the chopper switch S is off, as the inductor current can not die down instantaneously, this current is forced to flow through the diode and load for a time Toff.

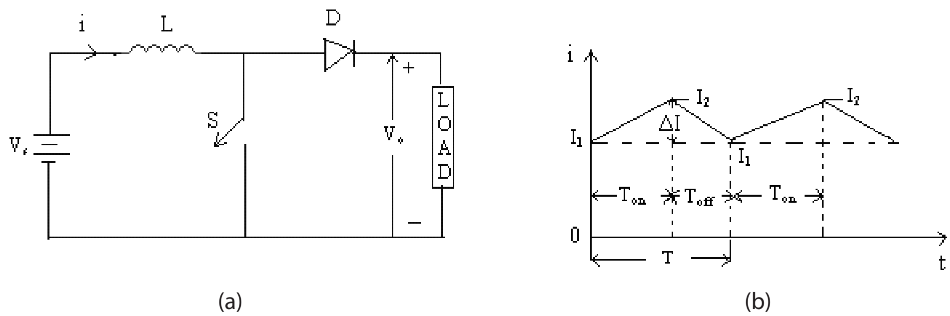

Fig. 5: (a) Step up chopper, (b) Current waveform

As the current tends to decrease, polarity of the emf induced in L is reversed. As a result, voltage across the load given by V_o + L (di/dt), exceeds the source voltage V_s. In this manner, the circuit acts as a step up chopper and the energy stored in the inductor L is released to the load.[11] When the switch S is on, current through the load would increase from I_1 to I_2 as shown in Figure 5 (b). When Switch S is off, current would fall from I_2 to I_1. With S on, source voltage applied to L i.e., $V_L = V_s$. When S is off, $V_L = V_o - V_s$.

Energy input to inductor from the source during the period Ton is

$$W_{in} = \text{(voltage across L)(average current through L) Ton}$$

$$= V_s\left(\frac{I_1 + I_2}{2}\right)T_{on} \qquad \ldots(1.15)$$

During the time T_{off}, when S is off, thee energy released by inductor to the load is

$$W_{off} = \text{(voltage across L)(average current through L) } T_{off}$$

$$= (V_o - V_s)\left(\frac{I_1 + I_2}{2}\right)T_{off} \qquad \ldots(1.16)$$

Considering the system to be lossless, these two energies given by equations (1.15) and (1.16)

$$V_s\left(\frac{I_1 + I_2}{2}\right)T_{on} = (V_o - V_s)\left(\frac{I_1 + I_2}{2}\right)T_{off} \qquad \ldots(1.17)$$

$$V_o = V_s\left(\frac{T}{T-T_{on}}\right) = V_s\left(\frac{1}{1-d}\right) \quad \text{…(1.18)}$$

It can be concluded from equation (1.18) that the average voltage value across the load can be stepped up by varying the duty cycle (d). If switch is S is always off, d=0 and $V_o=V_s$. If the switch S is always on, d=1 and $V_o=\infty$ (infinity). In practice, switch S is turned on and off so that d is variable and the required step up average output voltage, more than source voltage is obtained.[11]

1.2.5 PWM Inverter

The converter that converts or inverts a DC voltage to an alternating voltage is called an inverter. For providing an adjustable – frequency power to industrial applications, three – phase inverters are more common than single – phase inverters. Three phase inverters, like single phase inverters, take their input DC voltage from a battery or more usually from a rectifier. A basic three phase inverter is a six step bridge inverter[14] and it uses a minimum of six semiconductor switches.

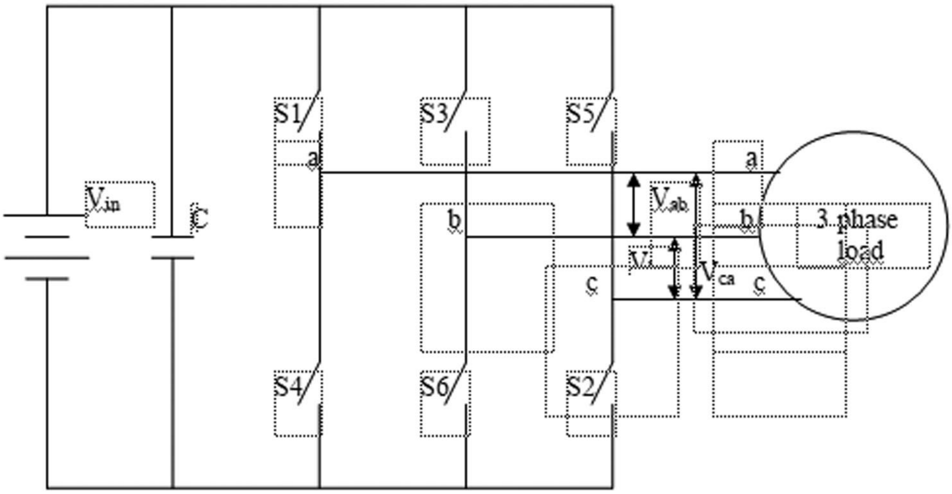

Fig. 6: Three phase bridge inverter

In inverter terminology, a step is defined as a change in the firing from one switch to the next switch in proper sequence. For one cycle of 360º, each step would be of 60º interval for a six step inverter. This means that switches would be biased at regular intervals of 60º in proper sequence so that three phase AC voltage is synthesized at the output terminals of a six step inverter. In many industrial applications, control of the output voltage of inverters is often necessary 1. to cope with the variations of DC input voltage, 2. to regulate voltage of inverters and 3. to satisfy the constant voltage and frequency control requirement. There are various techniques to vary the inverter output voltage. The most efficient method of controlling the output voltage and gain is to incorporate PWM control within the inverters. If δ_m is the width of m^{th} pulse and b is the number of pulse, then the rms output voltage can be found by[11]

$$V_{ac} = V_{in}\left(\sum_{m=1}^{2b}\frac{\delta_m}{\pi}\right)^{\frac{1}{2}} \qquad \ldots(1.19)$$

This type of modulation eliminates all harmonics less than or equal to 2b-1.For b=5, the Lower Order Harmonic is ninth.

1.3 Mathematical Modelling and Analysis of Wind Electric System

The model contains the following subsystem.

1. Wind turbine model
2. Permanent Magnet synchronous generator model
3. Power Converters model

1.4 Wind Turbine Model[5]

The power captured by the wind turbine is P = $\frac{1}{2}\pi\rho R^3 V^2 C_p$ …(1.20)

The power coefficient C_p is a nonlinear function of wind velocity and blade pitch angle and is highly dependent on the constructive characteristics of the turbine. It is represented as a function of tip speed ratio λ

$$\lambda = \frac{R\omega_t}{V} \qquad \ldots(1.21)$$

It is important to remark the aerodynamic efficiency is maximum at an optimum tip speed ratio. The turbine torque is obtained by dividing turbine power by turbine speed.

$$T_t(V,\omega_t) = \frac{1}{2}\pi\rho R^2 C_t(\lambda) V^3 \qquad \ldots(1.23)$$

Where C_t (λ) is the torque co-efficient of the turbine and is given by

$$C_t(\lambda) = \frac{C_p(\lambda)}{\lambda} \qquad \ldots(1.24)$$

The power co efficient C_p is given by

$$C_p(\lambda) = \left(\frac{116}{\lambda_1} - (0.4\beta) - 5\right)0.5e^{\frac{-16.5}{\lambda_1}} \qquad \ldots(1.25)$$

where $\lambda_1 = \dfrac{1}{\left(\dfrac{1}{(\lambda + 0.089\beta)} - \dfrac{0.035}{\beta^3 + 1}\right)}$ ...(1.26)

1.5 Mathematical Equations[7]

A simple method for modeling the wind turbine is shown in Figure 7. The mass of the shaft as seen from the generator is very small and it is neglected. The inertia of the turbine gives a negative contribution to the when generator is in generating mode. The model of the wind turbine is described by the following differential equations

$$\frac{d\omega_t}{dt} = \frac{1}{J_t}\left[T_t(V,\omega_t) - T_S\right]$$
$$\frac{dT_S}{dt} = K_S\left[\omega_t - \omega_g\right] + \frac{B_S}{J_t}\left[T_t(V,\omega_t) - T_S\right] + \frac{B_S}{J_g}\left[T_g\left(\cos\alpha,\omega_g\right) - T_S\right]$$
$$\frac{d\omega_g}{dt} = \frac{1}{J_g}\left[T_g\left(\cos\alpha,\omega_g\right) - T_S\right] \quad \text{...(1.27)}$$

The generator torque in terms of rotor reference frame variables is given as

$$T_g = \frac{3}{2}\frac{P}{2}\left[i_d i_q\left(L_q - L_d + \lambda_m i_q\right)\right] \quad \text{...(1.28)}$$

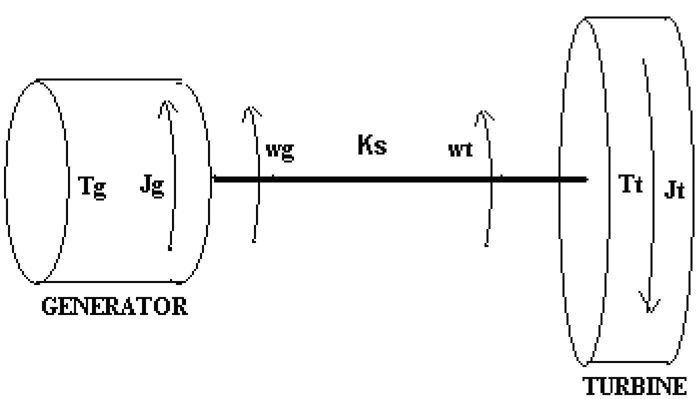

Fig. 7: Generator and turbine torque interaction

1.6 Analysis of Overall Wind Electric System

Analysis of Horizontal axis wind turbine driven PMSG is done by coupling Wind Turbine model, PMSG model and Power Converters model. Analysis is carried out for various wind velocities. Output voltage with constant amplitude and frequency is obtained with the help of Power Converters for irrespective of wind velocities. Figure 8 shows the overall Simulation model of Wind Electric System. This model is simulated for various wind velocities and analysis is done. The simulation results are shown in Figures 9 to 16.[15]

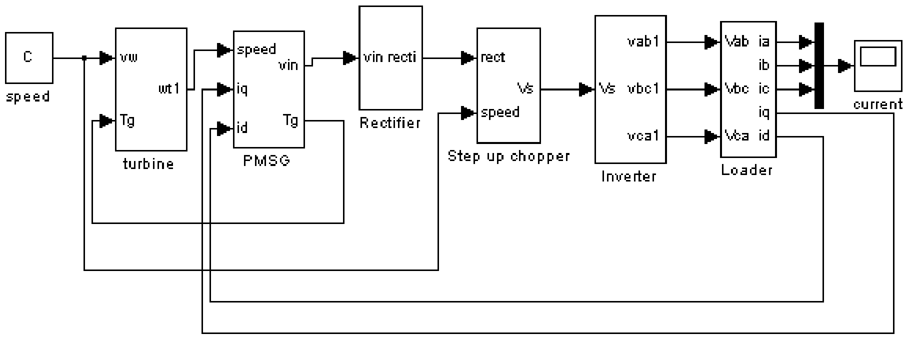

Fig. 8: Simulation model of wind electric system

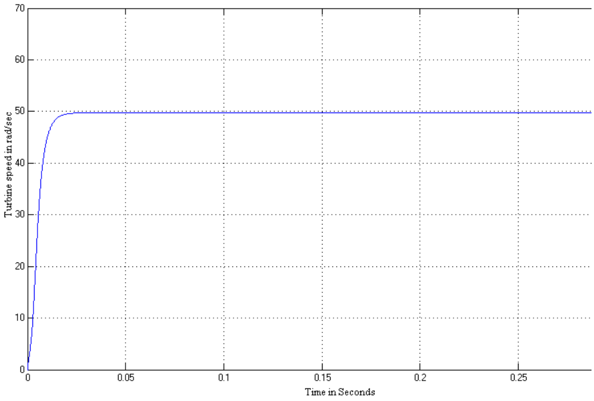

Fig. 9: Wind turbine speed curve for the wind velocity of 10 m/s

Depending upon the wind velocity wind turbine speed is varied.

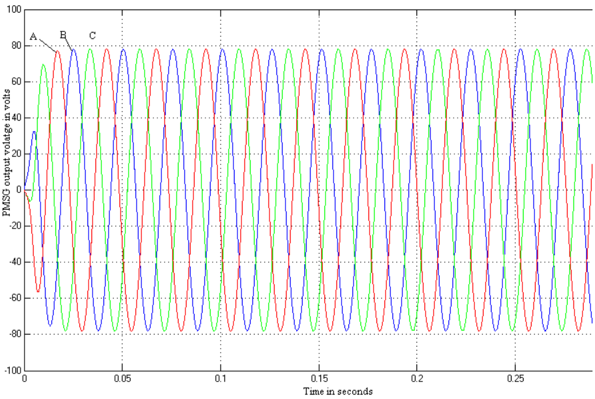

Fig. 10: PMSG output voltage curve for the wind velocity of 10 m/s

Figure 10 shows the PMSG output voltage curve for the wind velocity of 10 m/s. PMSG output voltage is increased with the increase in wind turbine speed.

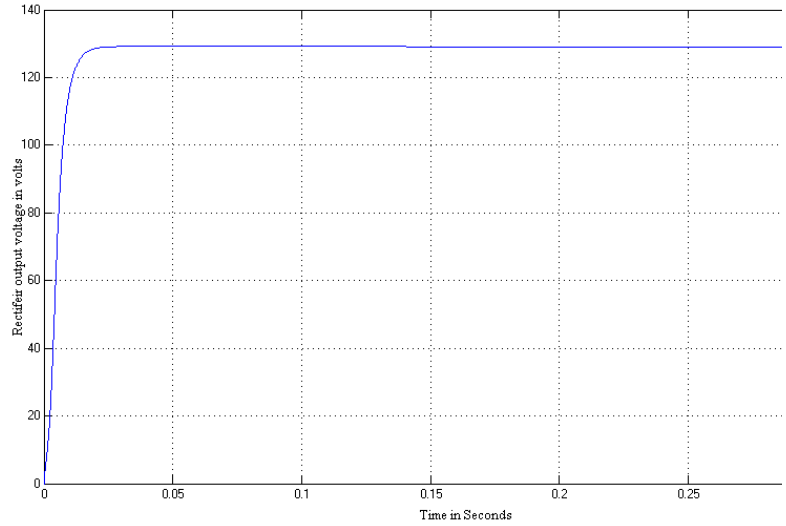

Fig. 11: Rectifier output voltage for the wind velocity of 10 m/s

Theoretical Value of Rectifier output voltage for input voltage of 78.3 V

$$V_{dc} = 129.5\text{volts}$$

Simulation result V_{dc} = 129.1 volts

From the simulation result, it can be concluded that the simulation result is nearer to the theoretical value.

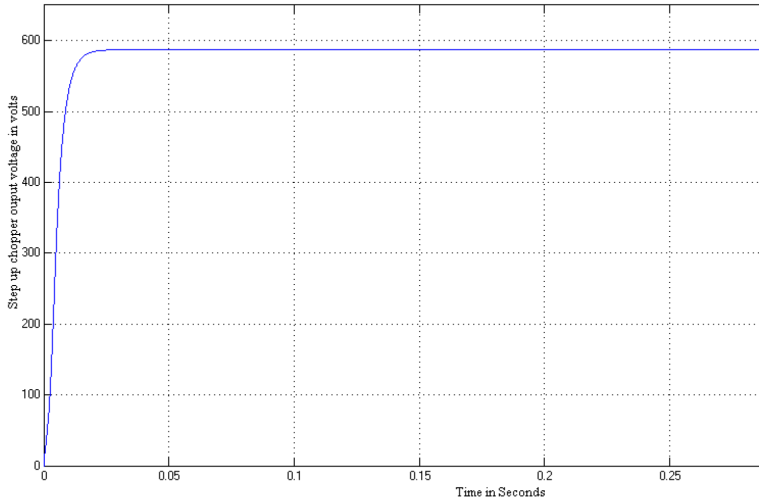

Fig. 12: Step up chopper output DC voltage curve for the wind velocity of 10 m/s

Figure 12 shows the Step up chopper output voltage for the wind velocity of 10 m/s. Theoretical value of step up chopper for the input voltage of 129.1 V, V_o =586.8 V with duty ratio of 0.78. From the simulation results shows that the output voltage of the chopper is stepped up depending upon the duty ratio of the chopper circuit.

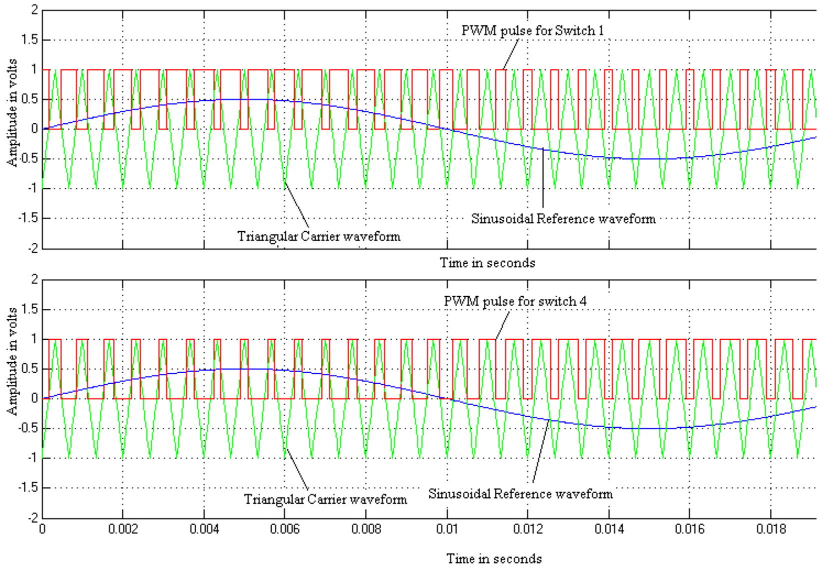

Fig. 13a: PWM pulse generation for Phase A leg in three phase inverter

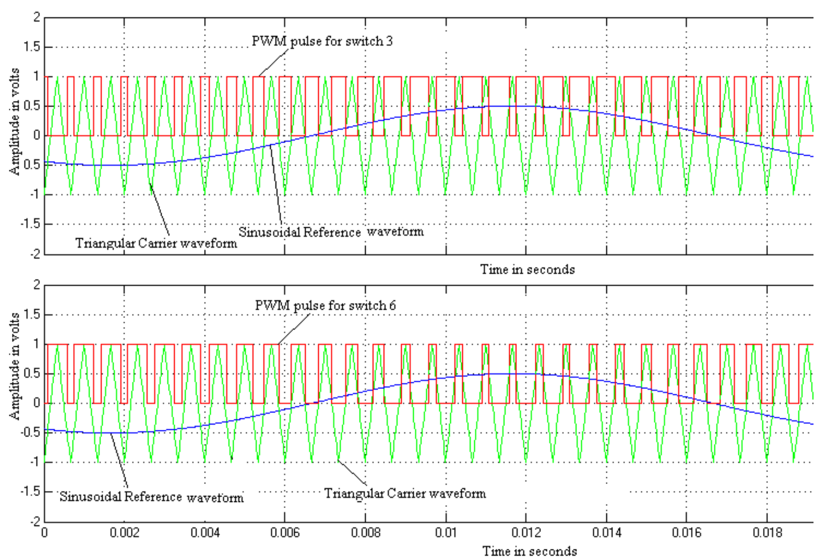

Fig. 13b: PWM pulse generation for Phase B leg in three phase inverter

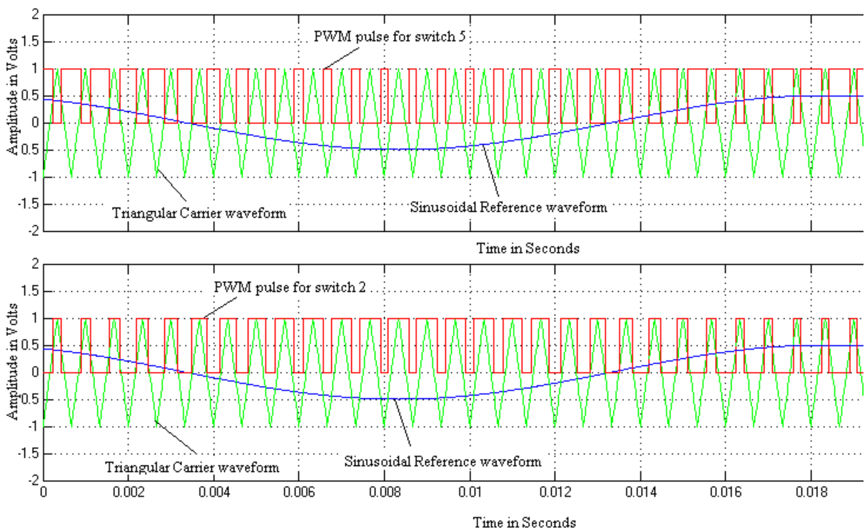

Fig. 13c: PWM pulse generation for Phase C leg in three phase inverter

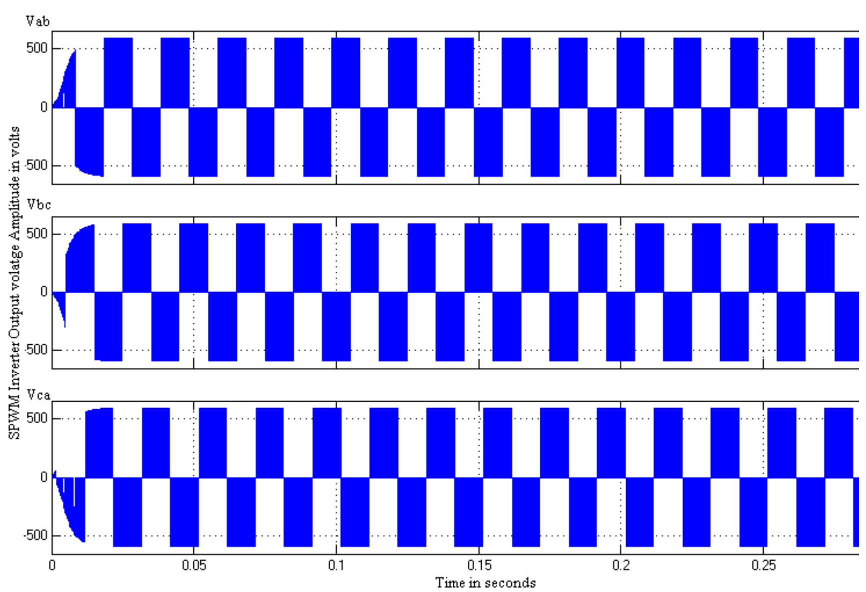

Fig. 14: SPWM inverter output voltage for the wind velocity of 10 m/s

The above simulation results for SPWM inverter shows that the output voltage frequency depends upon the frequency of the reference waveform and the width of the pulses can be varied by varying the modulation index (ratio of amplitude of reference voltage and carrier voltage amplitude) of the Sinusoidal Pulse Width Modulation technique. Due to which the average output voltage can be varied.

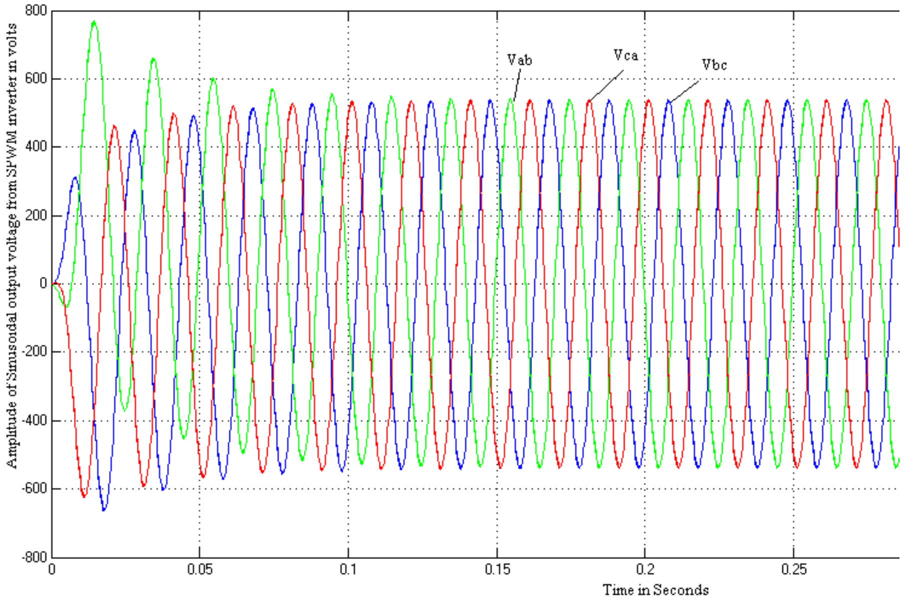

Fig. 15: Sinusoidal output voltage of SPWM inverter for the wind velocity of 10 m/s

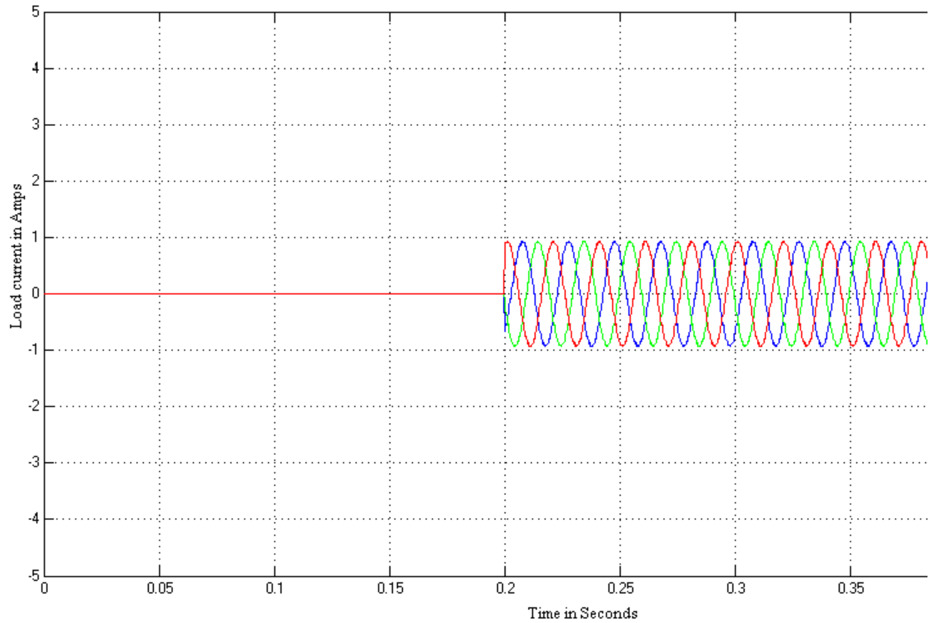

Fig. 16: Load current waveform for a resistive load of 580 ohms (loaded at t = 0.2 sec)

Figure 15 shows the sinusoidal output voltage waveform from the Sinusoidal pulse width modulated inverter.

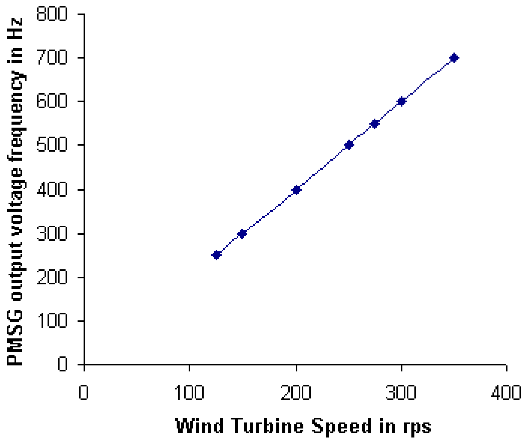

Fig. 17: Turbine speed PMSG output voltage frequency characteristics of wind electric system

Table 1: Details of duty ratio for different wind speed

Wind Speed (rad/Sec)	*PMSG output voltage (Volts)*	*Rectifier Output voltage (Volts)*	*Duty ratio for chopper*	*Chopper Output voltage (volts)*	*Inverter output voltage (peak) (volts)*
5	38.9	64.13	0.89	586.5	586.5
6	46.8	77.14	0.86	586.2	586.2
8	62.6	103.2	0.82	586.1	586.1
10	78.3	129.2	0.78	587	587
11	86.2	142.1	0.75	584.6	584.6
12	94.0	155.2	0.74	587.1	587.1
14	109.9	181.2	0.69	586.4	586.4
15	117.5	194.2	0.67	586.2	586.2

The analysis of Wind Electric shows that the frequency, amplitude of the PMSG output voltage increases with increase in wind turbine speed or wind velocity. Constant output voltage with constant frequency can be obtained from the power converters which are coupled with Permanent Magnet Synchronous generator. Depending upon the wind speed, duty ratio of the step up chopper can be varied to get the boost up voltage with constant magnitude.

Conclusion

The Horizontal axis wind turbine driven Permanent Magnet Synchronous Generator is modeled using MATLAB/SIMULINK tool and is also analyzed for various wind velocities. As the speed increases, both frequency and amplitude of the output voltage from the Permanent magnet synchronous generator also increases. In order to obtain the constant output voltage with constant frequency the PMSG is coupled with the Power converters. An uncontrolled rectifier rectifies the output voltage of PMSG and rectified output is given to the Step up chopper in order to boost up the voltage. Step up chopper produces constant DC voltage irrespective of wind velocities. The constant DC voltage from the Step up chopper is given to the input of Sinusoidal Pulse Width Modulated (SPWM) inverter to obtain an AC output voltage of constant amplitude with constant frequency. There by Constant output voltage with constant frequency is obtained from the proposed Wind Electric System.

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APPENDIX

Simulation Parameters

Wind Turbine: 1 - HP, Air density = 1.225 kg/m^3, Blade Radius = 1.5 m, Pitch Angle = 19°, Gear ratio = 5, Moment of Inertia = 0.05 kg/m^2, Shaft compliance coefficient = 0.05, Damping Coefficient = 0.1

PMSG: 1 – HP, 208 V, 60 Hz, 4 Pole, Stator resistance per phase = 1.5 ohm, Q axis Inductance = 0.05 H, D axis Inductance = 0.05 H, Amplitude of Flux Linkages established by the Permanent Magnet = 0.314 V/rad/sec, Moment of inertia = 2 kg/m^2

10

Electrical Circuits

***[1]Dr. M. Siva Ramkumar, [2]Dr. ir. V.M. Mansoor, [3]Mrs. P. Nagaveni, [4]Dr. A. Amudha**

[1,2,3]Assistant Professor Department of EEE, Faculty of Engineering,
Karpagam Academy of Higher Education

[4]Professor Head Department of EEE, Faculty of Engineering,
Karpagam Academy of Higher Education

*E-mail: sivaram0699@gmail.com

1.1 Basic Concepts

In electrical engineering, we are often interested in communicating or transferring energy from one point to another. To do this requires an interconnection of electrical devices. Such interconnection is referred to as an electric circuit, and each component of the circuit is known as an element.

Definition: An electric circuit is an interconnection of electrical elements.

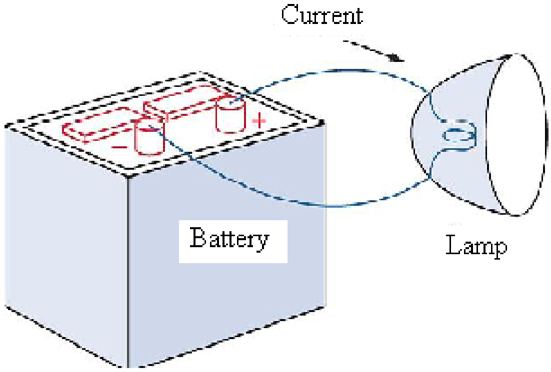


Fig. 1.1: Simple Electric Circuits

1.2 Systems of Units

As engineers, we deal with measurable quantities. Our measurement must be communicated in standard language that virtually all professionals can understand irrespective of the country. Such an international measurement language is the International System of Units (SI).

In this system, there are six principal units from which the units of all other physical quantities can be derived.

Table 1: Basic Quantities		
Quantity	***Basic Unit***	***Symbol***
Length	meter	m
Mass	kilogram	Kg
Time	second	S
Electric Current	ampere	A
Temperature	kelvin	K
Luminous Intensity	candela	cd
Charge	coulomb	C

One great advantage of SI unit is that it uses prefixes based on the power of 10 to relate larger and smaller units to the basic unit.

Table 2: Multiplier		
Multiplier	***Prefix***	***Symbol***
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

1.3 Basic Definitions

Electric Current

It is defined as rate of flow of electric charge. The unit of current is ampere.

$$i = \frac{dq}{dt}$$

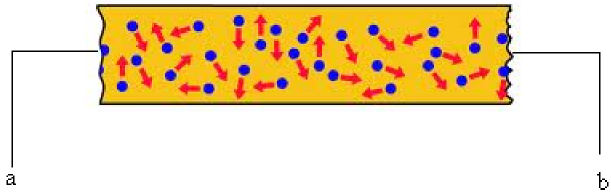


Fig. 1.2: Movement of free electron in a conducting material before applying electric potential

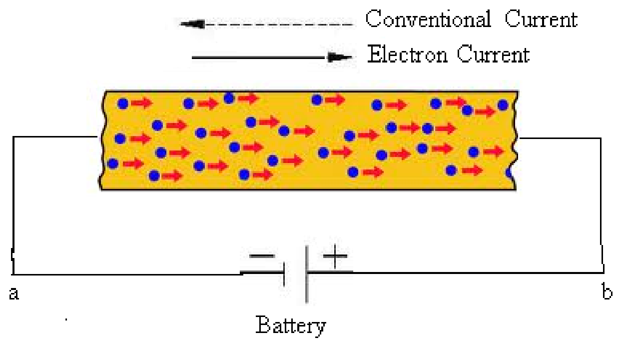


Fig. 1.3: Movement of free electron in a conducting material after applying electric potential

Usually the flow of direct current is assumed to be from positive terminal (Anode) to negative terminal (Cathode). This current is said to be conventional current flow. If the direction of current is from cathode to anode, then it is called electron current.

Electric Potential

It is the work done in moving a charge of one coulomb between two points. Its unit is volt.

$$E = \frac{dW}{dQ}$$

Electric Resistance

The resistance of a circuit is the property by which it opposes the flow of current. The unit of resistance is ohms (Ω).

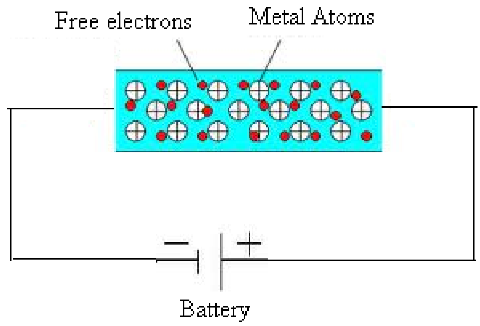


Fig. 1.3: Collision of free electron with metal atoms

When an voltage is applied, the free electron moves and they collide with other atoms. The collision between the free electron and the atoms is reflected as an 'opposition' to the flow of free electron. That means, this collision process 'resists' the flow of free electron. Hence it is referred to as the resistance of the material.

Resistance in Terms of Physical Quantities

The resistance of a conductor depends on

a. its length (l)
b. Cross-sectional area (a)
c. material of the conductor
d. temperature

The resistance of a material is given by,

$$R = \frac{\rho l}{a}$$

where,

ρ – Specific resistance or resistivity in ohm-m

Electrical Conductance

The reciprocal of resistance is called conductance. Its unit is mho ($\mho$)

$$G = \frac{1}{R}$$

Similarly the reciprocal of resistivity is called conductivity (σ).

$$\sigma = \frac{1}{\rho}$$

Its unit is Siemen/metre.

Power

It is defined as rate of doing work. Unit of power is Watts.

$$P = VI$$

where,

V – Potential difference in volts

I – Electric current in ampere

Energy

It is the amount of work done for 't' seconds.

$$\text{Energy} = P \times t$$
$$= VI \times t$$

Unit of energy is watt-hour.

Types of Elements

There are two types of elements found in electrical circuits.

1) Active elements (is capable of generating energy), e.g., generators, batteries, and operational amplifiers (Op-amp).
2) Passive element (is capable of absorbing energy), e.g., resistors, capacitors and inductors.

PROBLEMS

1. In a circuit, 100 C of charge circulates at a constant rate for every 5 seconds. Find the current.

   Given:

$$dq = 100\ C$$
$$dt = 5\ sec$$

Solution:

The current flowing through the circuit is given by,

$$i = \frac{dq}{dt}$$
$$= \frac{100}{5}$$
$$i = 20A$$

2. An electric heater draws 12A at 230V for a period of 3 hours. If electrical energy costs 40 paise per unit, find the cost of operating the heater.

   Given:

$$V = 230V$$
$$I = 12A$$
$$t = 3\ \text{hours}$$
$$\text{unit cost} = 40\ \text{paise}$$

Solution:

The energy consumed by the electric heater is,

$$E = P \times t$$
$$= V \times I \times t$$

$$= 230 \times 12 \times 3$$
$$= 8280 \text{ Watt-hour}$$
$$E = 8.280 \text{ kWatt-hour}$$

If cost is 40 paise for 1kWatt-hour, then cost for 8.280 kWatt-hour is,

$$= 8.28 \times 40$$
$$= 331.2 \text{ paise}$$
$$= 3.312 \text{ Rs.}$$

Note: 1 Unit = 1 kWatt-hour

3. Calculate the resistance of 100 m length wire having a uniform cross-sectional area of 0.1 sq.mm. If the wire is made up of a material having a resistivity of 50×10^{-8} ohm metre.

   Given:

$$l = 100\text{m}$$
$$a = 0.1\text{sq.mm}$$
$$= 0.1 \times 10^{-6} \text{ m}^2$$
$$\rho = 50 \times 10^{-8} \text{ ohm metre}$$

Solution:

The resistance of a material is given by,

$$R = \frac{\rho\, l}{a}$$

$$= \frac{50 \times 10^{-8} \times 100}{0.1 \times 10^{-6}}$$

$$R = 500\ \Omega$$

1.4 Ohm's Law

Ohms law, sometimes more correctly called Ohm's Law, named after Mr. Georg Ohm, mathematician and physicist born 1789 and died 1854 in Bavaria, defines the relationship between power, voltage, current and resistance. These basic electrical units apply to direct current, or alternating current. Ohm's Law is the foundation of electronics and electricity. These formulae are very easy to learn and are used extensively by electricians. Without a thorough understanding of "Ohm's Law" an electrician would either design or troubleshoot even the simplest of electronic or electrical circuits.

When a voltage is applied to a closed circuit, it causes a flow of electrons and consequently a current in the circuit. The resistance of the circuit opposes this flow.

The actual value of the current flowing depends on the applied emf and resistance in the circuit, the relationship being given by Ohm's law.

Statement

When the temperature remains constant, current flowing through a circuit is directly proportional to potential difference across the conductor.

Mathematically, we may write

$$E \propto I \quad \text{(or)} \quad V \propto I$$

Therefore, $V = \text{Constant} \times I$

This constant is the resistance (R) of the material. Hence,

$$V = IR$$

Taking the above equation into account, the formula for power can be written as

$$P = VI$$

$$= I^2R \; [V = IR]$$

$$P = \frac{V^2}{R} \quad \left[I = \frac{V}{R} \right]$$

Therefore, according to Ohm's law:

1. Current is directly proportional to voltage. If voltage is increased by a given percentage, current increase by the same percentage. If the voltage is decreased by a given percentage, current decreases by the same percentage.
2. Current is inversely proportional to resistance. An increase in resistance results in a decrease in current. A decrease in resistance results in an increase in current.
3. It is important to note that resistance cannot be changed by changing voltage or current. Resistance in a circuit is a physical constant. Resistance in a circuit can only be changed by changing components or resistors rated at more or fewer ohms.

Limitations of Ohm's Law

- Not applicable to non-linear devices such as diodes, zener diode, voltage regulators etc.
- Does not hold good for non-metallic conductors such as silicon carbide.

PROBLEMS

1. A 110 volt wall outlet supplies power to a strobe light with a resistance of 2200 ohms. How much current is flowing through the strobe light?

Given:

$$V = 110V$$
$$R = 2200 \text{ ohms}$$

Solution:

The current flowing through strobe light is

$$I = \frac{V}{R} \quad \text{(by Ohm's Law)}$$

$$= \frac{110}{2200}$$

$$I = 0.05A$$

2. A CD player with a resistance of 40 ohms has a current of 0.1 amps flowing through it. Sketch the circuit diagram and calculate how many volts supply the CD player.

Given:

$$I = 0.1A$$
$$R = 40 \text{ ohms}$$

Solution:

Circuit diagram

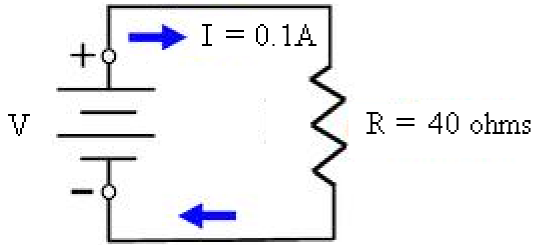


Fig. 1.4

The voltage supplied for CD player is

$$V = IR$$
$$= 0.1 \times 40$$
$$= 4V$$

3. What is the resistance of the circuit conductor when the conductor voltage drop is 3 volts and the current flowing through the conductor is 100 amperes?

Given:

$$V = 3V$$
$$I = 100A$$

Solution:

The resistance of the circuit conductor is

$$R = \frac{V}{I}$$

$$= \frac{3}{100}$$

R = 0.03 ohms

4. A potential difference of 10V is applied across a 2.5 ohm resistor. Calculate the current, power dissipated and the energy transformed into heat in 5 min.

Given:

V = 10V

R = 2.5 ohms

t = 5 min

Circuit diagram:

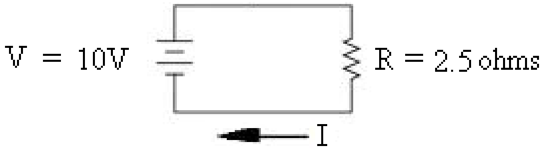


Fig. 1.5

Solution:

Current flowing in the circuit is

$$I = \frac{V}{R} \quad \text{(by Ohm's Law)}$$

$$= \frac{10}{2.5}$$

= 4A

Power dissipated in the resistor

P = VI

= 10 × 4

P = 40 Watts

Energy transformed into heat in 5 min is

E = P × t

= 40 × 5 × 60 [1 min = 60 sec]

P = 24000 Watt-sec

1.5 Kirchoff's Law

1. Kirchhoff's Current Law (I Law)

The sum of current flowing towards a junction is equal to the sum of current flowing away from it.

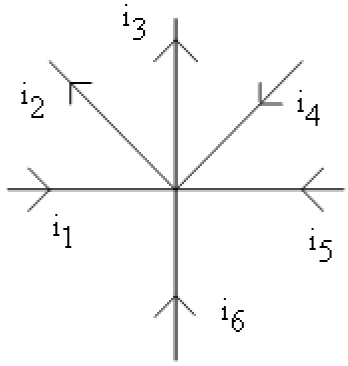


Fig. 1.6: Kirchhoff's Current Law

Consider a junction formed by 6 conductors. The current in these conductors are i_1, i_2, i_3, i_4, i_5 and i_6.

According to Kirchhoff's Current Law (KCL),

Sum of current entering a node = Sum of current flowing away from the node

$$i_1+i_4+i_5+i_6 = i_2+i_3$$

2. Kirchhoff's Voltage Law (II Law)

In a closed circuit, the sum of the potential drops is equal to the sum of the potential rises.

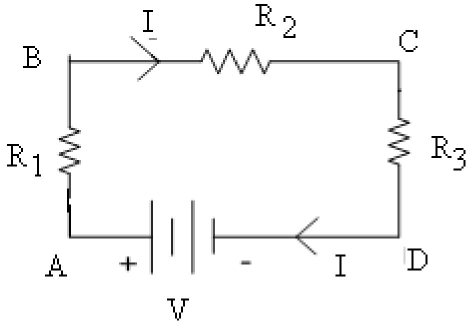


Fig. 1.7: Kirchhoff's Voltage Law

Fig – ABCDA forms a closed circuit.

From A -> D, the potential drops across R_1, R_2 and R_3 are of IR_1, IR_2 and IR_3 respectively.

From D -> A, the potential rise is V volts.

Therefore, according to Kirchhoff's Voltage Law (KVL),

Sum of potential drops = sum of the potential rises

$$IR_1+IR_2+IR_3 = V$$

1.6 Resistances in Series

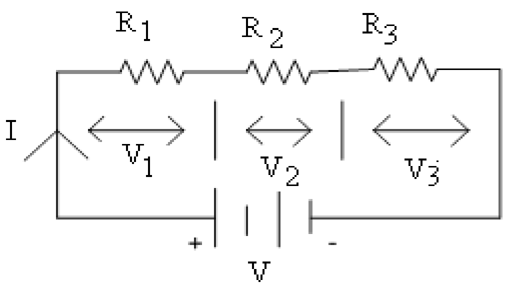


Fig. 1.7: Resistances in Series

where,

V – Supply voltage

V_1 – Voltage drop across resistor R_1

V_2 – Voltage drop across resistor R_2

V_3 – Voltage drop across resistor R_3

I – Circuit Current

By KVL,

$$V = V_1+V_2+V_3 \qquad \text{…(1)}$$

By Ohms law,

$$V = IR$$

Since this is a series circuit current I is constant. Hence

$$V_1 = IR_1$$

$$V_2 = IR_2$$

$$V_3 = IR_3$$

Therefore, (1) can be written as

$$IR = IR_1+IR_2+IR_3$$

$$IR = I\,(R_1+R_2+R_3)$$

$$R = R_1+R_2+R_3$$

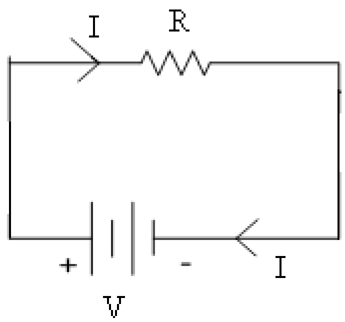


Fig. 1.8 Equivalent circuit

where,

R – Total circuit resistance

Power across (or) Power dissipated across each resistor is given by

$$\text{Power across resistor } R_1 = P_1 = I^2R_1 = \frac{V_1^2}{R_1}$$

$$\text{Power across resistor } R_2 = P_2 = I^2R_2 = \frac{V_2^2}{R_2}$$

$$\text{Power across resistor } R_3 = P_3 = I^2R_3 = \frac{V_3^2}{R_1}$$

Total power supplied,

$$\begin{aligned} P &= P_1 + P_2 + P_3 \\ &= I^2R_1 + I^2R_2 + I^2R_3 \\ &= I^2(R_1 + R_2 + R_3) \end{aligned}$$

Similarly total power can be also be found from,

$$P = VI = \frac{V^2}{R}$$

Therefore in Series circuit,

1. The same current flows through all the resistances.
2. For each resistance, there will be a voltage drop according to Ohm's law.
3. The sum of the voltage drops will be equal to the applied voltage according to Kirchhoff's voltage law.

PROBLEMS

1. A lamp rated 500W, 100V is to be operated from 220V supply. Find the value of the resistor to be connected in series with the lamp. What is the power lost in the resistor?

   Given:

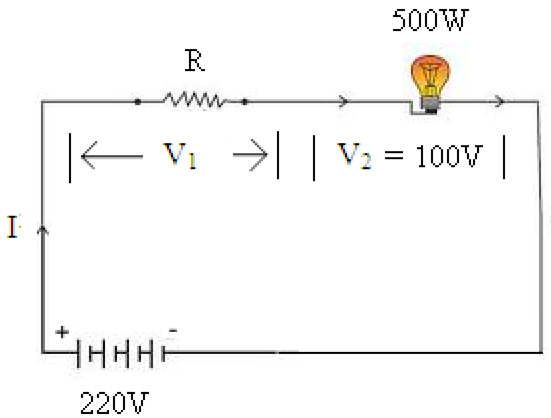


Fig. 1.9

Solution:

By KVL,

Potential rise = sum of voltage drops

$$220 = 100 + V_1$$

$$V_2 = 120V$$

The voltage drop across the lamp is 100V. Power consumed by lamp is 500W.

W.K.T.

$$P = VI$$

$$I = \frac{P}{V}$$

$$= \frac{500}{100}$$

$$= 5A$$

In a series circuit, current is constant.

Therefore value of R is

$$R = \frac{V_2}{I}$$

$$= \frac{120}{24}$$

$= 24$ ohms

Power lost in the resistor $= I^2R$

$= 5^2 \times 24$

$= 600W$

Note:

Input power $= P_{in} = VI$

$= 220 \times 5$

$= 1100W$

Also, P_{in} = power consumed by lamp + power lost in the resistor

$= 500 + 600$

$= 1100W$

Therefore, P_{in} = Sum of powers consumed by load

2. A resistor of ohmic value 30Ω is connected in series with an unknown resistor. The potential drops across the two resistances are 144 and 96 volts respectively. Find the value of the unknown resistor.

Given:

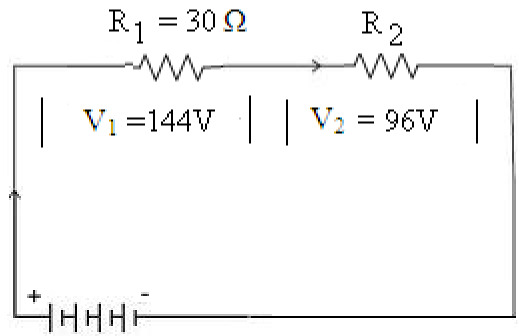


Fig. 1.10

Solution:

The voltage drop across 30Ω resistor is

$V_1 = IR_1$

$144 = I \times 30$

$I = 4.8A$

The voltage drop across resistor 'R' is

$V_2 = IR_2$

$$96 = 4.8 \times R_2$$
$$R_2 = 20\Omega$$

Hence, the value of the unknown resistor R_2 is 20 ohms.

3. Three resistors Ra, Rb, Rc connected in series to 250V source. Given Rc = 50Ω and Eb = 80V when the current is 2A. Calculate the resistances Ra and Rb.

   Given:

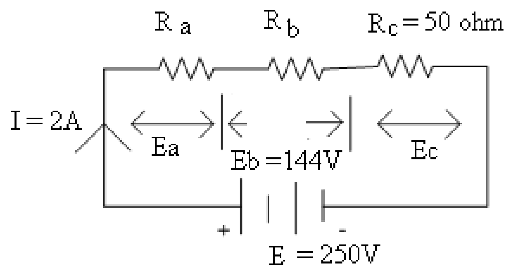


Fig. 1.11

Solution:

The voltage drop across Rc is

$$Ec = I \times Rc$$
$$= 2 \times 50$$
$$Ec = 100V$$

Since, $E = Ea + Eb + Ec$ (by KVL)

$$250 = Ea + 80 + 100$$

Therefore, $Ea = 70V$

Hence,

$$Ra = \frac{Ea}{I}$$
$$= \frac{70}{2}$$
$$Ra = 35 \text{ ohms}$$

Similarly,

$$Rb = \frac{Eb}{I}$$
$$= \frac{80}{2}$$
$$Ra = 40 \text{ ohms}$$

1.7 Resistances in Parallel

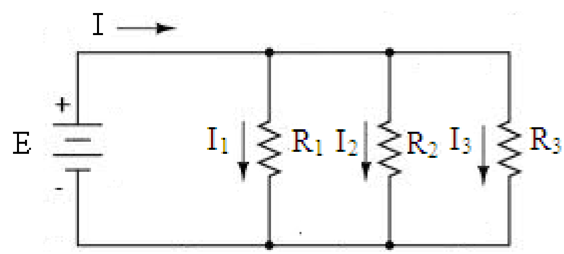


Fig. 1.12

Fig.1.12 shows three resistances R_1, R_2 and R_3 connected in parallel and current through theses resistors are I_1, I_2 and I_3 respectively.

It should be noted that in a parallel circuit the voltage across each resistor is same.

Therefore,

$$I_1 = \frac{E}{R_1}$$

$$I_2 = \frac{E}{R_2}$$

$$I_3 = \frac{E}{R_3}$$

By KCL,

$$I = I_1 + I_2 + I_3$$

$$\frac{E}{R} = \frac{E}{R_1} + \frac{E}{R_2} + \frac{E}{R_3}$$

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

If there were two resistors in parallel, then the above equation can be written as

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

Therefore, the total resistance or the equivalent resistance when two resistors connected in parallel is given by,

$$R = \frac{R_1 R_2}{R_1 + R_2}$$

Hence in a Parallel circuit,

1. The voltage across each resistance is same.
2. Total circuit current is equal to sum of branch currents by KCL.
3. Current in each branch is given by Ohm's law.

PROBLEMS

1. The effective resistance of two resistors connected in series is 100 Ω. When connected in parallel, then effective value in 24 ohm's. Determine the value of two resistors

Solution:

The equivalent or effective resistance when two resistors are connected in series is given by,

$$Req = R_1 + R_2$$

$$R_1 + R_2 = 100\ \Omega \quad \ldots(1)$$

$$R_2 = 100 - R_1 \quad \ldots(2)$$

The equivalent or effective resistance when two resistors are connected in parallel is given by,

$$R_1R_2/R_1+R_2 = 24 \quad \ldots(3)$$

Substituting equation (1) in (3), we get

$$R_1R_2/100 = 24$$

$$R_1R_2 = 2400 \quad \ldots(4)$$

Substituting equation (2) in (4), we get

$$R_1\ (100-R_1) = 2400$$

$$100\ R_1-R_1\text{^}2-2400 = 0$$

$$R_1\text{^}2-100\ R_1 + 2400 = 0$$

$$(R_1-60)(R_1-40) = 0$$

Therefore, R1 = 60 Ω (or) R1 = 40 Ω

When $R_1 = 60\Omega$; $R_2 = 100 - 60 = 40\Omega$

When $R_1 = 40\Omega$; $R_2 = 100 - 40 = 60\Omega$

2. Two resistors connected in parallel across 200V supply take 10A from the mains. If the power dissipated in one resistor is 800W, find the value of the other resistor. Also find current flowing through each resistors.

Given:

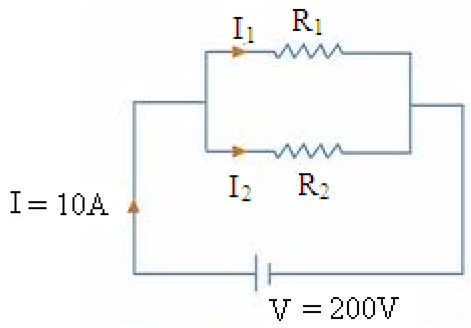


Fig. 1.13

Power dissipated in R_1 is 800W

Solution:

The power input is given by,

$$P_{in} = V \times I$$
$$= 200 \times 10$$
$$= 2000W$$

But, P_{in} = Power dissipated across R_1 + Power dissipated across R_2

$$2000 = 800 + P_2$$

Therefore,

$$P_2 = 1200W$$

The power dissipated across R_2 is,

$$P_2 = \frac{V^2}{R_2}$$

The value of resistance R_2 is,

$$R_2 = \frac{V^2}{P_2}$$
$$= \frac{200 \times 200}{1200}$$

Therefore,

$$R_2 = 33.33\Omega$$

Current flowing through R_2 is,

$$I_2 = \frac{V}{R_2}$$

$$= \frac{200}{33.33}$$

$$= 6.006A$$

By KCL,

$$I = I_1 + I_2$$

$$10 = I_1 + 6.006$$

Therefore,

$$I_1 = 3.994A$$

3. Find the equivalent resistance between two points A & B shown in Fig. 1.14.

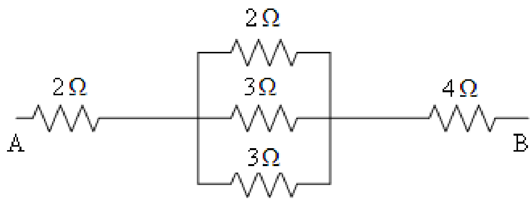


Fig. 1.14

Solution:

Step 1: The three resistances 2, 3 and 3 ohms are in parallel. The equivalent resistance for three resistances connected in parallel is given by,

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$= \frac{1}{2} + \frac{1}{3} + \frac{1}{3}$$

$$\frac{1}{R} = 1.17$$

Therefore, $R = 0.8547\Omega$

Step 2:

Now, the resistances 2Ω, 0.8547Ω and 4Ω are connected in series. The equivalent resistance for three resistances connected in series is given by,

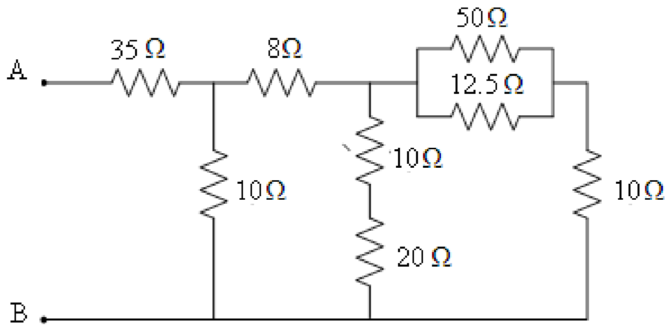
$$R = R_1 + R_2 + R_3$$

$$= 2 + 0.8547 + 4$$

$$= 6.8547\Omega$$

Hence, the equivalent resistance between two points A & B is 6.8547Ω

4. Determine the equivalent resistance between terminals A & B shown in Fig. 1.15.



Solution:

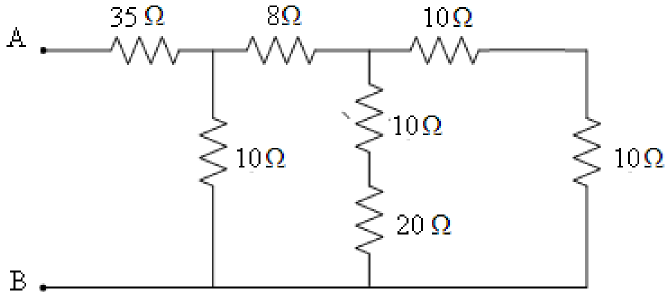
Step 1: The two resistances 50 and 12.5 ohms are in parallel. The equivalent resistance for two resistances connected in parallel is given by,

$$R = \frac{R_1 R_2}{R_1 + R_2}$$

$$= \frac{50 \times 12.5}{50 + 12.5}$$

$= 10\Omega$

Now, the circuit can be reduced as



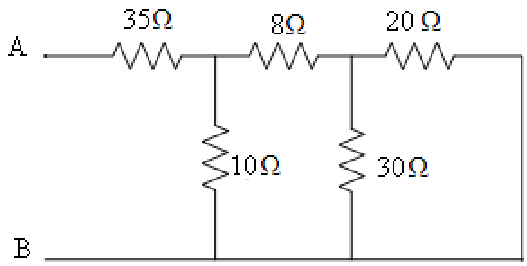
Step 2: The two resistances 10 and 10 ohms are in series. The equivalent resistance for two resistances connected in series is given by,

$$R = R_1 + R_2$$
$$= 10 + 10 = 20\Omega$$

Also, resistances 10 and 20 ohms are in series. Hence,

$$R = R_1 + R_2$$
$$= 10 + 20 = 30\Omega$$

Now, the circuit can be reduced as



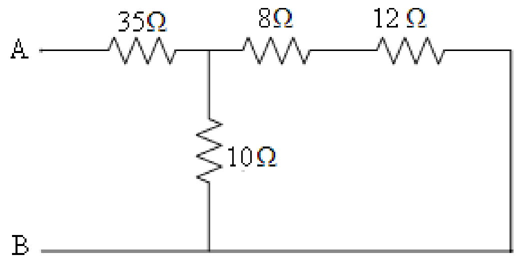
Step 3: The two resistances 20 and 30 ohms are in parallel. The equivalent resistance for two resistances connected in parallel is given by,

$$R = \frac{R_1 R_2}{R_1 + R_2}$$

$$= \frac{30 \times 20}{30 + 20}$$

$= 12\Omega$

Now, the circuit can be reduced as



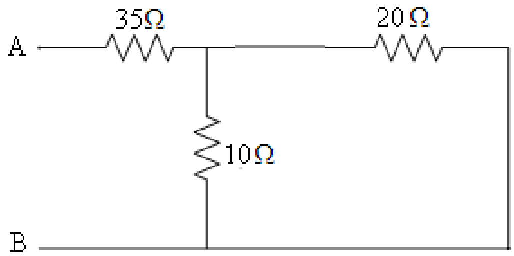
Step 4: The two resistances 8 and 12 ohms are in series. The equivalent resistance for two resistances connected in series is given by,

$R = R_1+R_2$

$= 8 + 12$

$= 20\Omega$

Now, the circuit can be reduced as

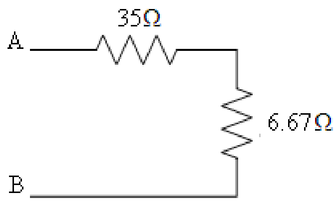


Step 5: The two resistances 20 and 10 ohms are in parallel. The equivalent resistance for two resistances connected in parallel is given by,

$$R = \frac{R_1 R_2}{R_1 + R_2}$$

$$= \frac{20 \times 10}{20 + 10} = 6.67\Omega$$

Now, the circuit can be reduced as



Step 6: Finally, the two resistances 35 and 6.67 ohms are in series. The equivalent resistance for two resistances connected in series is given by,

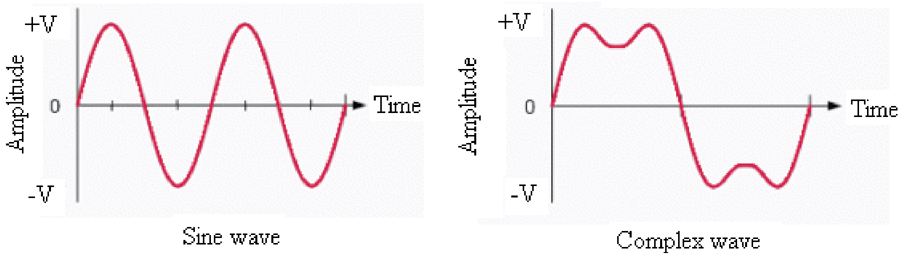
$$R = R_1 + R_2$$

$$= 35 + 6.67 = 41.67\Omega$$

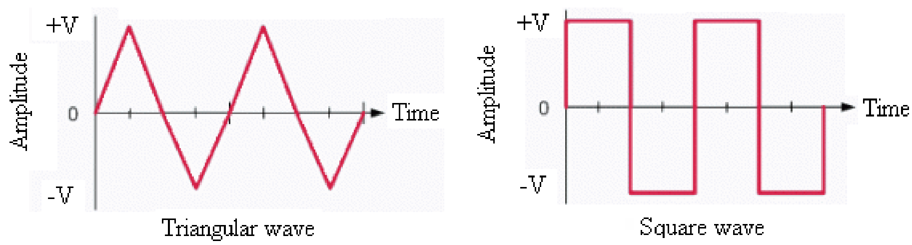
Therefore, the equivalent resistance between terminals A & B is 41.67Ω.

1.8 Introduction to AC Circuits

The alternating current (AC) waveforms refer to continually changing time-varying voltages and currents. In a set manner from a minimum to a maximum value in a specific time interval, the magnitude and direction of these voltages and currents vary. This is in contrast to direct current (DC), where voltages or currents do not change in magnitude or direction since they are unidirectional. As shown in Fig.1.16, AC waveforms can be sinusoidal (sine wave), complex, square or triangular.



(a) (b)



(c) (d)

Fig. 1.16: Different AC Waveforms

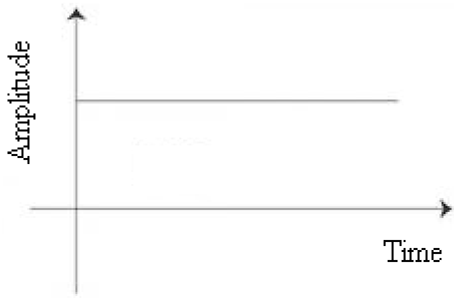


Fig. 1.17: DC Waveform

The waveform in Fig. 1.17 shows the DC voltage pattern from which it is clear that the voltage magnitude does not vary with respect to time. Therefore it is a time – independent quantity.

But the waveforms (a) to (d) in Fig. 1.16 show different AC waveforms whose voltage is not constant in magnitude and it varies with respect to time. Hence they are said to be time – dependent quantity.

They are said to be AC quantity since they have different values of magnitude at different intervals of time. These values are called instantaneous values of AC quantity. The formulas for instantaneous values are

$$v = V_m \sin\omega t \qquad \text{(for voltage waveform)}$$

$$i = I_m \sin\omega t \qquad \text{(for current waveform)}$$

It should be noted that the instantaneous values should be denoted by small letters.

The power supplies what we use as a consumer is mostly AC in nature. The pattern of AC used is sinusoidal.

Hence for analysis of an AC waveform, we use waveform (a) in Fig. 1.16 sine wave, which is a time – dependent quantity.

1.9 Different Terms Associated with a Sinusoidal Wave

Maximum value: The value of voltage at $\omega t = 90^o$, is maximum value or amplitude. Usually it is represented as V_m.

Peak-Peak value: It is the magnitude of voltage from positive peak to negative peak. It is denoted as V_{pp}.

Time period: It is the time taken to complete one cycle. It is denoted by T and its unit is second.

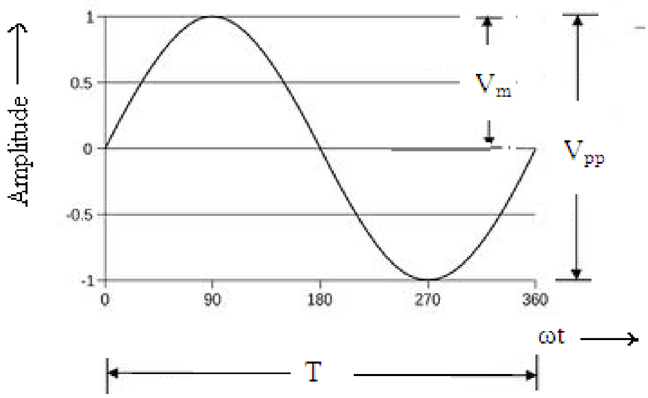


Fig. 1.18: AC - Pure Sine wave

Frequency: Frequency refers to the number of cycles completed in one second time period. It is commonly measured in cycles per second (cycles/sec) and is expressed in units of Hertz (Hz) and represented by the letter 'f'.

The general formula for frequency is

$$f = \frac{1}{T}$$

If frequency is 50Hz, it means 50 cycles are completed in one second.

The relation between angular velocity (ω) and frequency is

$$\omega = 2\pi f$$

Wavelength: Wavelength refers to the distance of the cycle of the wave to complete one cycle. Lambda (λ) is a Greek letter that is used to represent the wavelength in mathematical expression. It is similar to time period except that wavelength is measured in distance per cycle whereas time period is measured in time per cycle.

1.10 Measurement of Alternating Quantity

So far we know that AC voltage alternates in polarity and AC current alternates in direction. We also know that AC can alternate in a variety of different ways, and by tracing the alternation over time we can plot it as a "waveform." We can measure the rate of alternation by measuring the time it takes for a wave to evolve before it repeats itself (the "period"), and express this as cycles per unit time, or "frequency."

However, we encounter a measurement problem if we try to express how large or small an AC quantity is. Whereas in DC, measurement becomes easy, since the quantities voltage and current are generally stable.

There are notations by which an alternating quantity can be designated. They are:

1. Maximum value
2. Peak-Peak value
3. Average value
4. Root Mean Square (RMS) value

The above parameters are explained briefly as follows:

1. Maximum Value

One way to express the intensity, or magnitude (also called the amplitude), of an AC quantity is to measure its peak height on a waveform graph. This is known as the peak or crest value of an AC waveform.

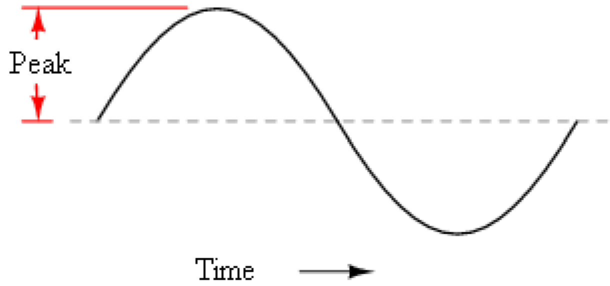


Fig. 1.19: Peak value

2. Peak-Peak Value

Another way is to measure the total height between opposite peaks. This is known as the peak-to-peak value of an AC waveform.

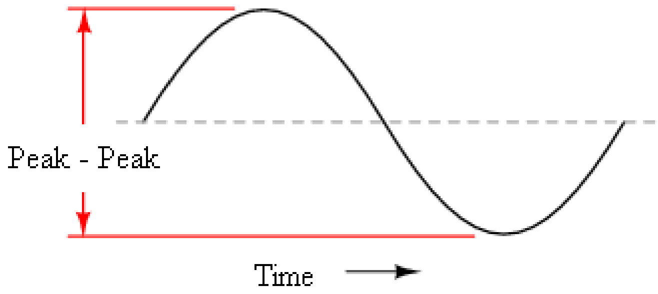


Fig. 1.20: Peak – Peak value

3. Average Value

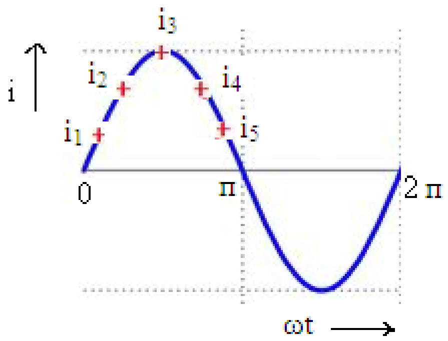


Fig. 1.21: Average value

The average value of a sine wave of voltage or current is the average of all the instantaneous values during one alternation.

For the above graph, average value is given by

$$I_{avg} = \frac{i_1 + i_2 + i_3 + i_4 + i_5}{5}$$

where,

i_1, i_2, i_3, i_4 and i_5 are instantaneous values.

Note: Usually average value has to be find by taking half- a-cycle. If entire cycle is taken, then the value will be zero, since the waveform is periodic.

Derivation: But for a sine wave, by mathematics the average value is

$$I_{avg} = \frac{\text{Area of half wave}}{\text{Base}}$$

Therefore, $$I_{avg} = \frac{1}{\pi}\int_0^{\pi} i\, d\theta$$

Sub, $i = I_m \sin\theta$

$$I_{avg} = \frac{1}{\pi}\int_0^{\pi} I_m \sin\theta\, d\theta$$

Solving the above integration, we get

$$I_{avg} = \frac{2\, I_m}{\pi}$$

Similarly if it is a sine voltage, then

$$V_{avg} = \frac{2\, V_m}{\pi}$$

Therefore, the average value is equal to 0.636 of the peak value.

4. Root Mean Square (RMS) Value

It is the root of mean of squared values over a full cycle. It is otherwise known as the effective value.

$$\text{RMS value} = \sqrt{\frac{\text{Area of the squared curve for one cycle}}{\text{Period}}}$$

$$\text{RMS value} = \sqrt{\frac{i_1^2 + i_2^2 + \ldots\ldots + i_N^2}{N}}$$

where,

i_1, $i_2 \ldots i_N$ are instantaneous values and N is the number of instantaneous values.

Derivation:

$$I_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} i^2\, d\theta}$$

$$= \sqrt{\frac{1}{2\pi}\int_{0}^{2\pi}(I_m \sin\theta)^2 d\theta}$$

$$= \sqrt{\frac{I_m^2}{2\pi}\int_{0}^{2\pi}(\sin\theta)^2 d\theta}$$

Hint: $\left[\text{Sub., } \sin^2\theta = \frac{1-\cos 2\theta}{2}\right]$

Solving the above integration, we get

$$I_{rms} = \frac{I_m}{\sqrt{2}}$$

Similarly if it is a sine voltage, then

$$V_{rms} = \frac{V_m}{\sqrt{2}}$$

PROBLEM

A current wave is represented by the equation i = 10 sin250t. Find (a) maximum value (b) rms value of current (c) frequency (d) time period.

Solution:

The instantaneous value of current is given by,

$$i = I_m \sin\omega t \qquad \text{...(1)}$$

The given equation is,

$$i = 10 \sin 250t \qquad \text{...(2)}$$

(a) Maximum value

Comparing (1) and (2), maximum value (I_m) is

$$I_m = 10A$$

(b) RMS value of current

The formula for RMS value of current is

$$I_{rms} = \frac{I_m}{\sqrt{2}}$$

$$= \frac{10}{1.414}$$

= 7.7A

(c) Frequency

Comparing (1) and (2),

$$\omega = 250$$

$$2\pi f = 250 \text{ [Since, } \omega = 2\pi f]$$

Therefore,

$$f = 250/2*3.14$$

$$f = 39.78\text{Hz}$$

(d) Time Period

The formula for time period in terms of frequency is,

$$T = \frac{1}{f}$$

$$= \frac{1}{39.78}$$

T = 0.025 sec

1.11 Power

Electric power is the rate at which electric energy is transferred by an electric circuit. The SI unit of power is the watt.

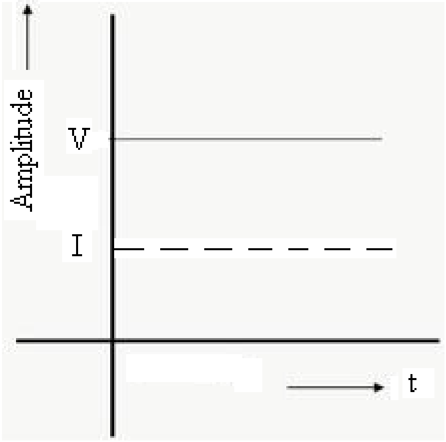


Fig. 1.22: Voltage and Current waveform in DC circuit

Fig. 1.22 shows the voltage and current waveform in DC circuit. Therefore in DC circuit, there is no phase difference between voltage and current. If 'Φ' is the phase difference, its value is zero, (ie., $\Phi = 0^o$).

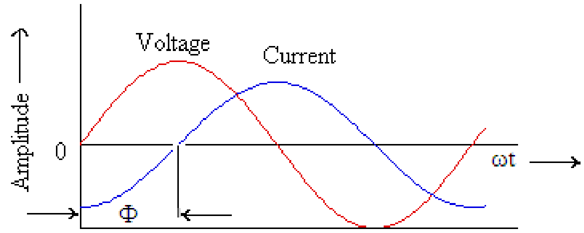


Fig. 1.23: Voltage and Current waveform in AC circuit

In the Fig.1.23, if the voltage waveform is taken as reference, the current waveform lags voltage waveform by an angle difference of 'Φ' degrees. Hence 'Φ' is said to be phase difference.

Therefore, considering the phase difference, the formula for power in ac circuit becomes,

$$P = VI \cos\Phi$$

Whereas in dc, the formula for power is

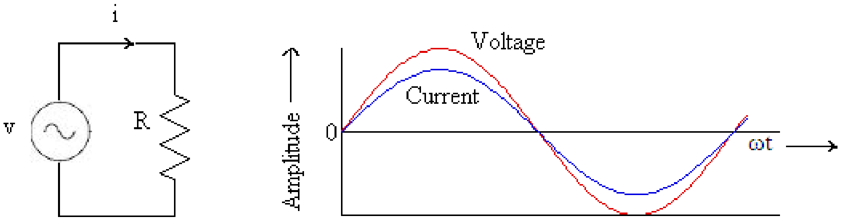
$$P = VI \text{ (Since } \Phi \text{ is zero)}$$

1.12 Types of Load

To understand the variation of phase difference Φ, different types of loads connected to ac supply is discussed below:

1. Resistive Load

When an resistive load is connected to an ac supply, the phase angle or difference between voltage and current waveform is zero as shown in Fig. 1.24.



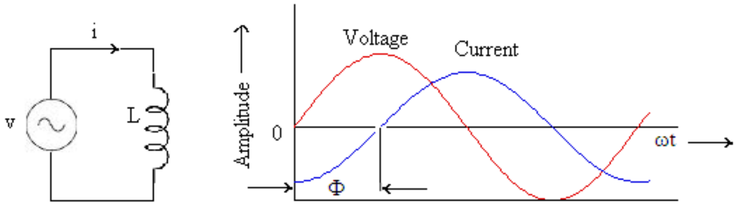
(a) Circuit Diagram (b) Voltage and Current waveform

Fig. 1.24: Resistive load connected to ac supply

Therefore, for an resistive load, $\Phi = 0^o$ and hence the formula for power is P = VI.

2. Inductive Load

When an inductive load is connected to ac supply, the current lags behind the voltage waveform as shown in Fig.1.25.



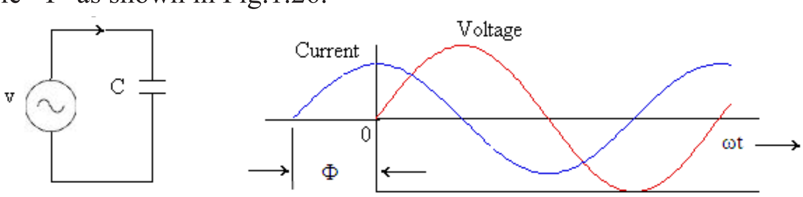
(a) Circuit Diagram (b) Voltage and Current waveform

Fig. 1.25: Inductive load connected to ac supply

In Fig.1.25 (b), current lags behind the voltage waveform by an angle ‘Φ’.

3. Capacitive Load

When the load is capacitive, the current waveform leads the voltage waveform by an angle ‘Φ’ as shown in Fig.1.26.



(a) Circuit Diagram (b) Voltage and Current waveform

Fig. 1.26: Capacitive load connected to ac supply

1.13 Types of Power

In alternating current circuits, energy storage elements such as inductance and capacitance may result in periodic reversals of the direction of energy flow. Therefore based on energy flow, the electrical power is classified as:

1. Real Power

The power that does the useful work is called real power. If the load is purely resistive, at every instant the product of voltage and current is positive, indicating that the direction of energy flow does not reverse. In this case, only real power is transferred.

Real power is given by,

$$P = VI \cos\Phi$$

where, V – rms value of voltage

I – rms value of current

Φ – phase angle between voltage and current

Real power is also called as true power. The unit of real power is Watts.

2. Reactive Power

It is the power that does do any useful work. It is also known as 'Wattless' or 'Idle' component.

Reactive power is given by,

$$P = VI \sin\Phi$$

If the loads are purely reactive, then the voltage and current are 90 degrees out of phase. For half of each cycle, the product of voltage and current is positive, but on the other half of the cycle, the product is negative, indicating that on average, exactly as much energy flows toward the load as flows back. There is no net energy flow over one cycle. In this case, only reactive energy flows—there is no net transfer of energy to the load.

The unit of reactive power is Volt-Ampere Reactive (VAR).

3. Apparent Power

Apparent power is the product of the root-mean-square of voltage and current. The formula for apparent power is,

$$P = VI$$

Practical loads have resistance, inductance, and capacitance, so both real and reactive power will flow to real loads. Power engineers measure apparent power as the magnitude of the vector sum of real and reactive power.

The unit of apparent power is Volt-Ampere (VA).

Power Triangle

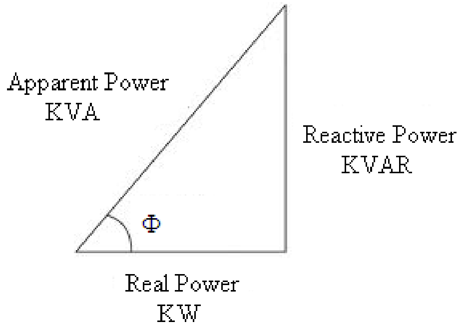


Fig. 1.27: Power Triangle

From the above right angled triangle (Fig. 1.27),

$$\text{hyp} = \sqrt{\text{opp}^2 + \text{adj}^2}$$

$$\text{Therefore, KVA} = \sqrt{\text{KW}^2 + \text{KVAR}^2}$$

Similarly,

$$\cos\Phi = \frac{\text{KW}}{\text{KVA}}$$

$$\text{KW} = \text{KVA}\cos\Phi$$

$$\text{ie., } P = VI\cos\Phi \qquad \text{(Real Power)}$$

and

$$\sin\Phi = \frac{\text{KVAR}}{\text{KVA}}$$

$$\text{Therefore, KVAR} = \text{KVA}\sin\Phi$$

$$\text{ie., } P = VI\sin\Phi \qquad \text{(Reactive Power)}$$

1.14 Power Factor

It is defined as the cosine of angle between voltage and current.

Power factor = $\cos\Phi$

The general formula for ac power is,

$$P = VI\cos\Phi$$

$$\text{Therefore, } \cos\Phi = \frac{P}{VI}$$

Types of Power Factor

1. Unity Power Factor

In resistive loads, the phase angle difference between voltage and current waveform is zero.

i.e., $\Phi = 0^o$

Therefore, $\cos\Phi = \cos 0^o = 1$

Since the value of $\cos\Phi = 1$, the power factor is said to be unity.

2. Lagging Power Factor

The loads which causes the current waveform to lag behind voltage produces lagging power factor. E.g. Inductive loads.

3. Leading Power Factor

The loads which causes the current waveform to lead the voltage produces leading power factor. E.g. Capacitive loads.

1.15 Single Phase AC Circuit

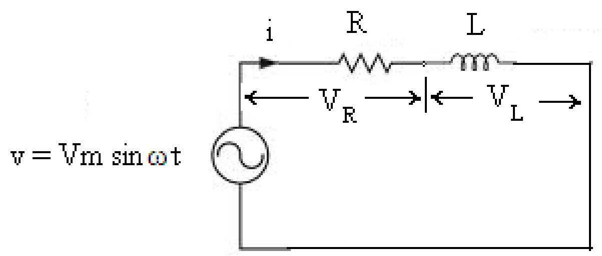


Fig. 1.28: RL Series circuit

In dc circuit, opposition to the flow of current is caused only by resistance. But in ac circuits, due to the presence of inductance and capacitance, opposition is produced by a term called reactance to the flow of current.

In the Fig.1.28 only inductance is present in series with resistance. Therefore, inductive reactance is given by

$$X_L = 2\pi fL \text{ ohms}$$

where, f – Frequency of ac supply

For the above circuit diagram,

$$V_R = IR$$

$$V_L = IX_L$$

where, V_R – Voltage drop across the resistance

V_L – Voltage drop across the inductor

I – RMS value of supply current

The total opposition offered by resistance and inductance to the flow of current is called impedance (Z).

The general formula for impedance is

$$Z = R + j(X_L \sim X_C) \qquad \text{(RLC Series circuit)}$$

where, X_C – Capacitive reactance

$$X_C = \frac{1}{2\pi fC}$$

In the circuit diagram in Fig.1.28, the element capacitor is not present.

Therefore, $Z = R + jX_L$ (Since $X_C = 0$)

If the circuit has only capacitance in series with the resistance, then

$$Z = R + jX_C \text{ (Since } X_L = 0)$$

Therefore in ac circuit, taking impedance into account, the formula for RMS value of supply voltage is

$$V = IZ$$

Impedance Triangle

An impedance triangle has resistance (always positive) in the x axis and reactance (at a right angle to resistance) in the y axis. The line that completes this triangle (the hypotenuse is the absolute value of the impedance.

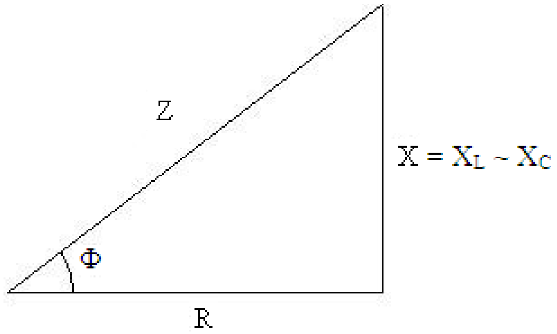


Fig. 1.29: Impedance Triangle

From the Fig.1.29,

Impedance Z is given by,

$$Z = \sqrt{R^2 + X^2}$$

Similarly,

$$\cos \Phi = \frac{R}{Z}$$

PROBLEMS

1. A coil having a resistance of 6Ω and an inductance of 0.03H is connected across a 50V, 60Hz supply. Calculate i) Supply current ii) Phase angle between the current and the applied voltage iii) Power factor iv) Real power

Given:

$R = 6\Omega$
$L = 0.03H$
$V = 50V$
$f = 60Hz$

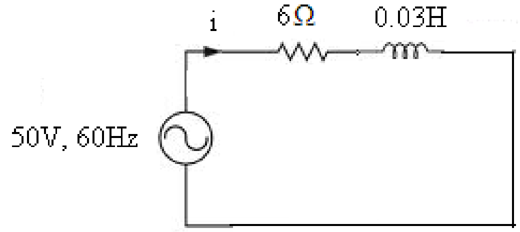


Fig.1.30 Circuit diagram

Solution:

(i) Supply current: In an ac circuit, the formula for RMS value of supply current is,

$$I = \frac{V}{Z}$$

$$Z = \sqrt{R^2 + X_L^2}$$

$$X_L = 2\pi fL$$
$$= 2 \times 3.14 \times 60 \times 0.03$$
$$X_L = 11.3\Omega$$

Therefore,

$$Z = \sqrt{6^2 + 11.3^2} = 12.8\,\Omega$$

Hence, RMS value of supply current is

$$I = \frac{V}{Z} = \frac{50}{12.8} = 3.9A$$

(ii) Power Factor:

$$\cos\Phi = \frac{R}{Z} = \frac{6}{12.8} = 0.468$$

(iii) Phase angle:

$$\cos\Phi = 0.468$$

$$\Phi = \cos^{-1}(0.468) = 27.9^{o}$$

(iv) Real power:

$$P = VI\cos\Phi$$

$$= 50 \times 3.9 \times 0.468 = 91.3 \text{ Watts}$$

2. A circuit draws a current of 10A at a voltage of 20000V and 0.8 power factor. Find i) Real power ii) Reactive power and iii) Apparent power.
   Given:

$$I = 10A$$

$$V = 20000V$$

$$\cos\Phi = 0.8$$

Solution:

(i) Real Power

The formula for real power is,

$$P = VI\cos\Phi$$

$$= 20000 \times 10 \times 0.8 = 160000 \text{ Watts} = 160 \text{ kWatts}$$

(ii) Reactive power:

The formula for real power is,

$$P = VI\sin\Phi$$

If $\cos\Phi = 0.8$, then

$$\Phi = \cos^{-1}(0.8) = 36.86^{o}$$

1.16 Three Phase Circuits

Most of the electrical power generated in the world today is three-phase. Three-phase power was first conceived by Nikola Tesla. In the early days of electric power generation, Tesla not only led the battle concerning whether the nation should be powered with low-voltage direct current or high-voltage alternating current, but he also proved that three-phase power was the most efficient way that electricity could be produced, transmitted, and consumed.

Advantages of Three Phase Circuits

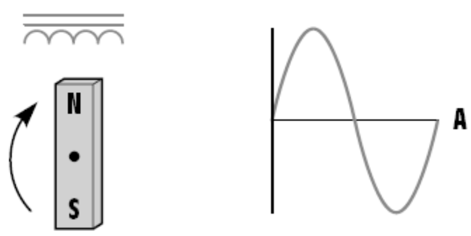
Comparing to single phase A.C. circuits, three phase circuits have the following advantages:

1. They have better power factor and efficiency.
2. For a given power rating, a three phase machine is smaller in size leading to saving in copper and other material.

3. Generation, transmission and utilization of power is more economical in three phase system.
4. For the same size, the capacity of three phase machine is higher.

Three Phase AC Power Generation

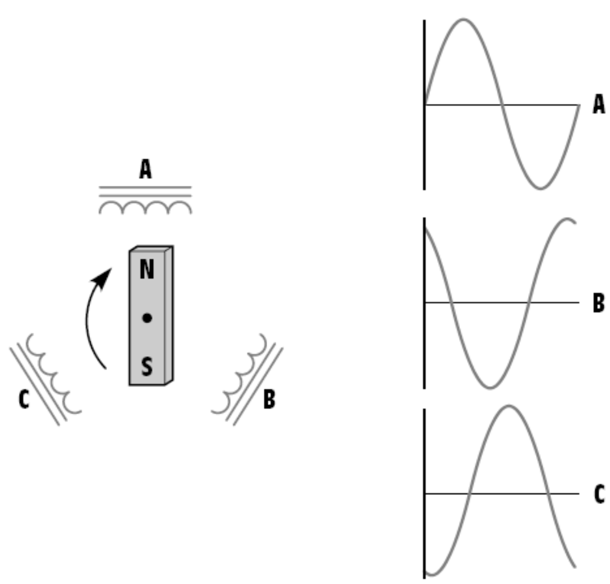
A single-phase alternating voltage can be produced by rotating a magnetic field through the conductors of a stationary coil, as shown in Fig. 1.31 (a).



(a) (b)

Fig. 1.31: Generation of Single phase power

Since alternate polarities of the magnetic field cut through the conductors of the stationary coil, the induced voltage will change polarity at the same speed as the rotation of the magnetic field. The alternator shown in Figure 1.31 (b) is single phase because it produces only one AC voltage.



(a) (b)

Fig. 1.31 Generation of Three phase power

If three separate coils are spaced 120° apart, as shown in Fig. 1.31 (a), three voltages 120° out of phase with each other will be produced (as shown in Fig.1.31 (b)) when the magnetic field cuts through the coils. This is the manner in which a three-phase voltage is produced.

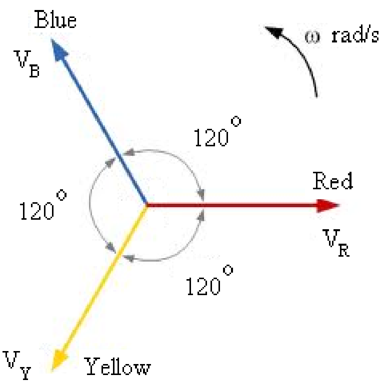


Fig. 1.31: Phase Voltage representation

Instantaneous values of induced phase voltages are

$$e_R = E_m \sin\omega t = E\angle 0^\circ$$

$$e_Y = E_m \sin(\omega t - 120^\circ) = E\angle -120^\circ$$

$$e_B = E_m \sin(\omega t - 240^\circ) = E_m \sin(\omega t + 120^\circ) = E\angle 120^\circ$$

Similarly, instantaneous values of phase currents are given by,

$$i_R = I_m \sin\omega t = I\angle 0^\circ$$

$$i_Y = I_m \sin(\omega t - 120^\circ) = I\angle -120^\circ$$

$$i_B = I_m \sin(\omega t - 240^\circ) = I_m \sin(\omega t + 120^\circ) = I\angle 120^\circ$$

Thus voltage in each winding differs by an angle of 120º. The magnitude of three voltages is equal.

Types of Three Phase Winding Connections

There are two basic three-phase connections, the wye or star connection and the delta connection.

1. Wye Connection

The wye or star connection is made by connecting one end of each of the three-phase windings together as shown in Fig. 1.32. The voltage measured across a single winding or phase is known as the phase voltage, as shown in Fig. 1.32. The voltage measured between the lines is known as the line-to-line voltage or simply as the line voltage.

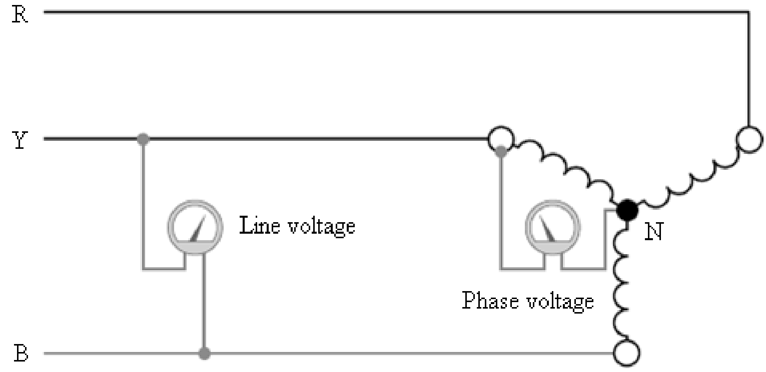


Fig. 1.32: Line voltage and Phase voltage measurement

In Figure 1.33, ammeters have been placed in the phase winding of a wye-connected load and in the line supplying power to the load. Voltmeters have been connected across the input to the load and across the phase. A line voltage of 208 V has been applied to the load. Notice that the voltmeter connected across the lines indicates a value of 208 V, but the voltmeter connected across the phase indicates a value of 120 V.

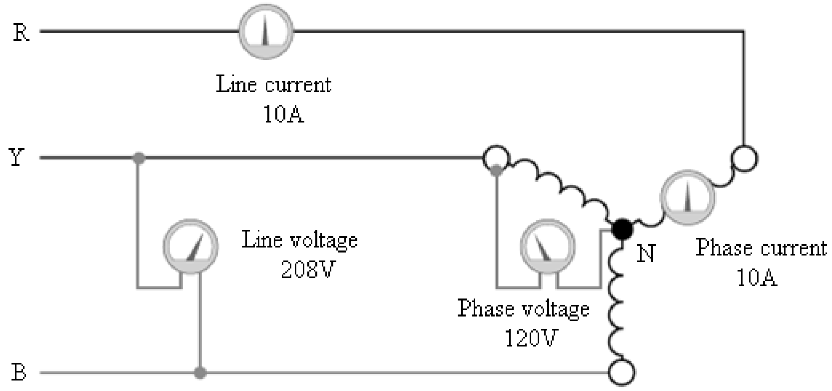


Fig. 1.33: Line current and Phase current measurement

The relation between line voltage and phase voltage in a star connected system is,

$$E_L = \sqrt{3}\ E_{ph}$$

where,

E_L – Line voltage

E_{ph} – Phase voltage

Therefore in a wye connected system, the line voltage is higher than the phase voltage by a factor of the square root of 3 (1.732).

Notice that in Fig. 1.33, 10 A of current flow in both the phase and the line. In a wye-connected system, phase current and line current are the same.

$$I_L = I_{ph}$$

where,

I_L – Line current

I_{ph} – Phase current

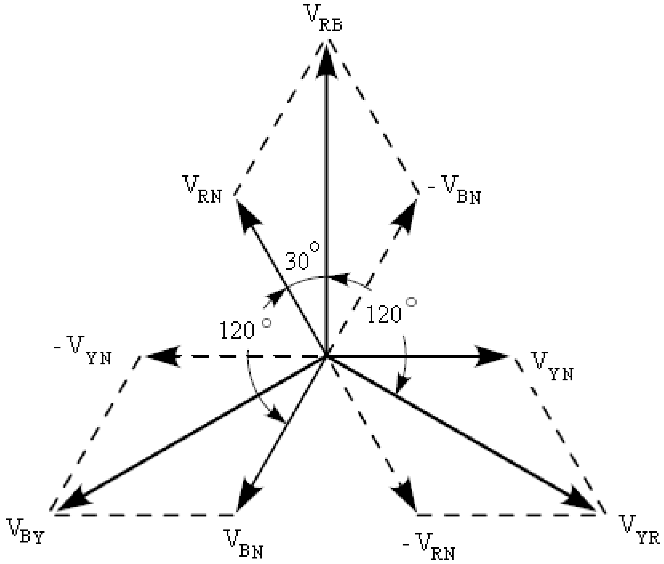


Fig. 1.34: Vector Diagram

where, V_{RN}, V_{YN}, V_{BN} – Phase voltages

V_{RB}, V_{YR}, V_{BY} – Line voltages

From the Fig.1.34, one can understand the following:

- The angle between phase voltage and line voltage is 30°.
- The angle between phase voltages is 120°.

2. Delta Connection

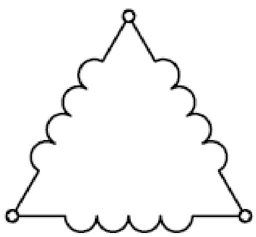


Fig.1.35: Delta connection

In Fig. 1.35, three separate inductive loads have been connected to form a delta connection. This connection receives its name from the fact that a schematic diagram of this connection resembles the Greek letter delta (Δ).

In Fig. 1.36, voltmeters have been connected across the lines and across the phase. Ammeters have been connected in the line and in the phase. **In the delta connection, line voltage (E_L) and phase voltage (E_{ph}) are the same.** Notice that both voltmeters indicate a value of 480 V.

i.e., $E_L = E_{ph}$

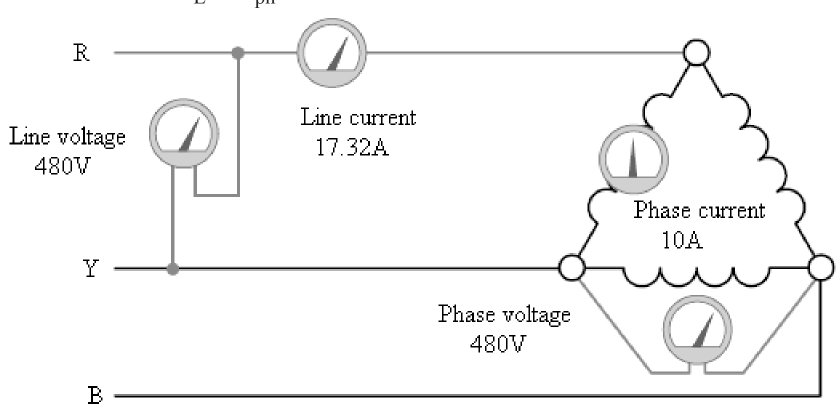


Fig.1.36: Voltage and current relationships in delta connection

Notice that the line current and phase current are different, however. **The line current of a delta connection is higher than the phase current by a factor of the square root of 3 (1.732).**

The relation between line current (I_L) and phase current (I_{ph}) is given by

$$I_L = \sqrt{3}\, I_{ph}$$

Three Phase Power

Sometime it becomes confused when computing power in three phase circuits. One reason for this confusion is that there are actually two formulas that can be used. If line values of voltage and current are known, the power can be computed using the formula:

$$P = \sqrt{3}\, V_L I_L \cos\Phi$$

If the phase values of voltage and current are known, the power can be computed using the formula:

$$P = 3\, V_{ph} I_{ph} \cos\Phi$$

Notice that in the first formula, the line values of voltage and current are multiplied by the square root of 3. In the second formula, the phase values of voltage and current are multiplied by 3. The first formula is used more often because it is generally more convenient to obtain line values of voltage and current, which can be measured with a voltmeter and clamp-on ammeter.

1.17 Balanced Three Phase Load

Balanced System

A balanced system means that the currents in the three phases are equal in magnitude and are displaced from one another by 120°.

A load is said to be a balanced load, if the impedance values in each phase are equal and hence the phase currents and power factors in the three phases are equal.

A balanced load is treated as three identical single phase loads.

PROBLEM

A balanced three phase load consists of a 6Ω resistor and 8Ω reactor (inductive) in each phase. The supply is 230V, 3Φ, 50Hz. Find (a) Phase current (b) Line current (c) total power. Assume the load to be connected in star. Also find when it is connected in delta.

Given:

$$R = 6\Omega$$
$$X_L = 8\Omega$$
$$V_L = 230V$$
$$f = 50Hz$$

Solution:

1) When the load is star connected:

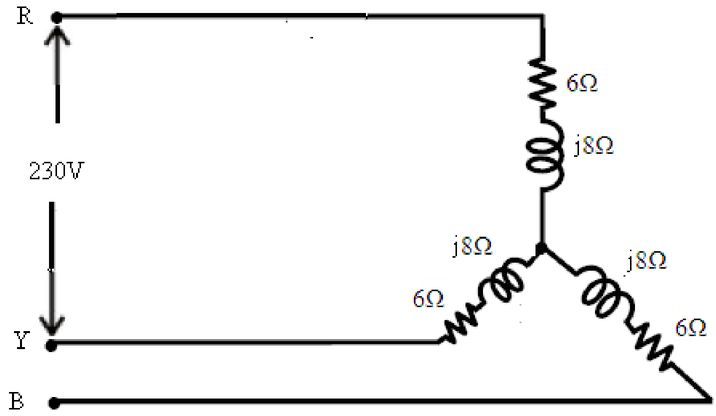


Fig. 1.37: Star Connection

(a) Phase current: The formula for phase current is,

$$I_{ph} = \frac{V_{ph}}{Z_{ph}}$$

Since the load is star connected,

$$V_L = \sqrt{3}\, V_{ph}$$

$$V_{ph} = \frac{230}{\sqrt{3}} = 132.8V$$

$$Z_{ph} = \sqrt{R^2 + X_L^2} = \sqrt{6^2 + 8^2} = 10\,\Omega$$

Therefore,

$$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{132.8}{10} = 13.28A$$

(b) Line current: For a star connected load,

$$I_L = I_{ph} = 13.28A$$

(c) Total power: Per phase power is given by,

$$P_{ph} = V_{ph} I_{ph} \cos\Phi$$

Phase impedance = 6 + j8

$$= 10\angle 53.1^\circ\ \Omega$$

Therefore, per phase power is

$$P_{ph} = 132.8 \times 13.28 \times \cos 53.1 = 1059 \text{ Watts}$$

Total power is given by,

$$P = 3\, V_{ph} I_{ph} \cos\Phi$$

$$= 3 \times 1059 = 3177 \text{ Watts}$$

2) When the load is delta connected:

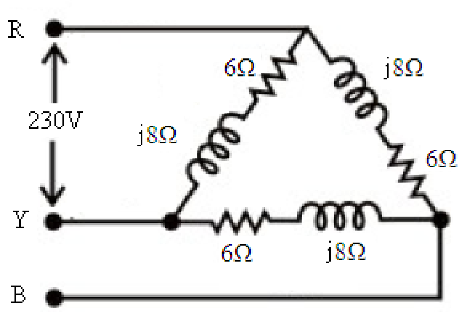


Fig. 1.37: Delta Connection

In delta connection,

$$E_L = E_{ph} = 230V$$

(a) Phase current:

$$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{230}{10} = 23A$$

(b) Line current: The formula for line current in delta connection is,

$$I_L = \sqrt{3}\, I_{ph}$$

$$= 1.732 \times 23 = 39.84A$$

(c) Total power:

$$P = 3\, V_{ph} I_{ph} \cos\Phi$$

$$= 3 \times 230 \times 39.84 \times \cos 53.1 = 9529 \text{ Watts}$$

1.18 Two Wattmeter Method of Measuring Three Phase Power

A wattmeter is an instrument with a potential coil and a current coil so arranged that its deflection is proportional to VIcosΦ, where V is the rms value of supply voltage applied across the potential coil, I is the rms value of supply current passing through the current coil, and Φ is the angle between voltage and current waveform. By inserting such a single phase wattmeter to measure the average real power in each phase (with its current coil in series with one phase of the load and its potential coil across the phase of the load), the total real power in a three phase system can be determined by the sum of the wattmeter readings. However, in practice, this may not be possible due to the nonaccessibility of either the neutral of the star connection, or the individual phases of delta connection.

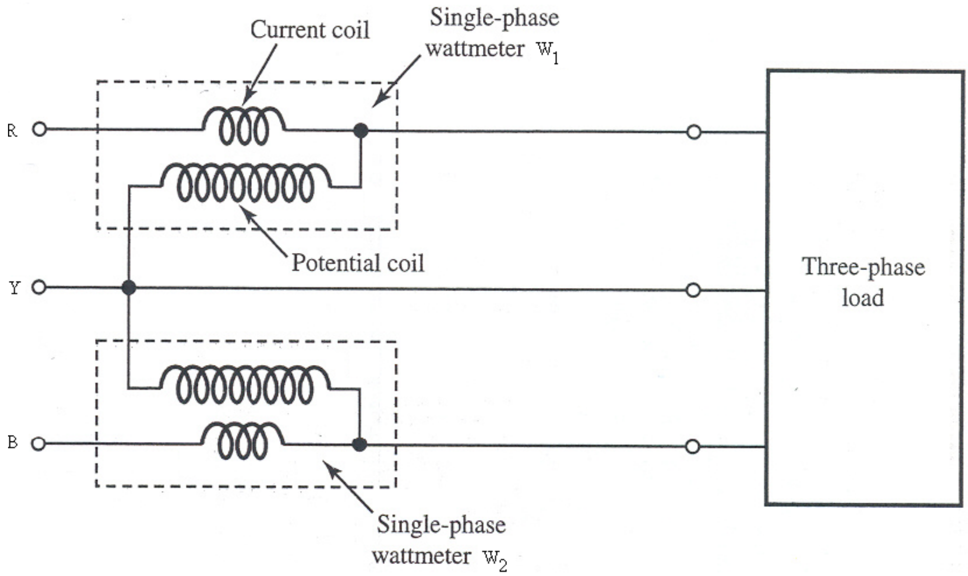


Fig. 1.38: Two Wattmeter method of Three phase Power measurement

Hence three phase power can be measured by means of only two single phase wattmeters having a common potential junction on any of the three lines in which there is no current coil as shown in Fig.1.38. This is known as the two wattmeter method of measuring three phase power. This method is valid for both balanced and unbalanced circuits with either the load or the source unbalanced. The total real power delivered to the load is given by the algebraic sum of the two wattmeter readings.

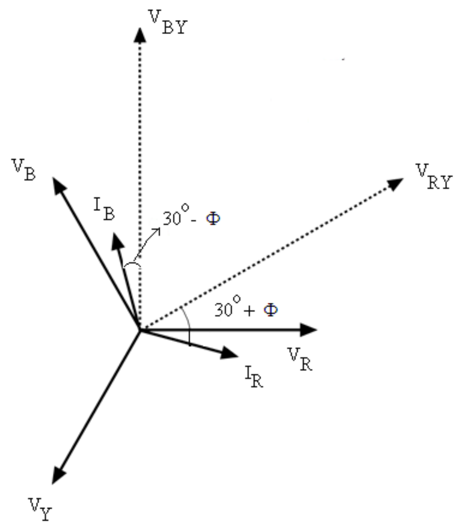


Fig.1.39: Vector Diagram

The wattmeter readings when connected as shown in Fig.1.38 are

$$W_1 = V_{RY} I_R \cos(30 - \Phi) \quad \ldots(1)$$

$$W_2 = V_{BY} I_B \cos(30 + \Phi) \quad \ldots(2)$$

The total power consumed by the load is given by,

$$W_1 + W_2 = V_{RY} I_R \cos(30 - \Phi) + V_{BY} I_B \cos(30 + \Phi)$$

$$= V_{RY} I_R (\cos(30 - \Phi) + \cos(30 + \Phi))$$

$$= V_{RY} I_R (\cos 30 \cos \Phi + \sin 30 \sin \Phi + \cos 30 \cos \Phi - \sin 30 \sin \Phi)$$

$$= V_{RY} I_R (2 \times \cos 30 \times \cos \Phi)$$

$$W_1 + W_2 = \sqrt{3}\ V_{RY} I_R \cos \Phi \quad \ldots(3)$$

Hence, the sum of the two wattmeter readings gives the total power consumption in the three phase load.

Similarly,

$$W_1 - W_2 = V_{RY} I_R \cos(30 - \Phi) - V_{BY} I_B \cos(30 + \Phi)$$

$$= V_{RY} I_R (\cos(30 - \Phi) - \cos(30 + \Phi))$$

$$= V_{RY} I_R (\cos 30 \cos \Phi + \sin 30 \sin \Phi - \cos 30 \cos \Phi + \sin 30 \sin \Phi)$$

$$= V_{RY} I_R (2 \times \sin 30 \times \sin \Phi)$$

$$W_1 - W_2 = V_{RY} I_R \sin \Phi \quad \ldots(4)$$

Equation (4) divided by (3) gives,

$$\frac{W_1 - W_2}{W_1 + W_2} = \frac{V_{RY} I_R \sin \Phi}{\sqrt{3}\ V_{RY} I_R \cos \Phi}$$

$$= \frac{\tan \Phi}{\sqrt{3}}$$

Therefore,

$$\tan \Phi = \sqrt{3}\ \frac{W_1 - W_2}{W_1 + W_2} \qquad \ldots(5)$$

From equation (5),

$$\Phi = \tan^{-1} \sqrt{3} \left(\frac{W_1 - W_2}{W_1 + W_2}\right)$$

Therefore, power factor is given by

$$\cos \Phi = \cos\left(\tan^{-1} \sqrt{3} \left(\frac{W_1 - W_2}{W_1 + W_2}\right)\right) \qquad \ldots(6)$$

PROBLEMS

1. Two wattmeters connected an 3-line, three phase ac to measure ac power and read 6717 watts and 2558 watts. Find the power drawn by the balanced load and its power factor.

   Given:

   $W_1 = 6717$ watts

   $W_2 = 2558$ watts

Solution:

Power drawn by the balanced load is

$$P = W_1 + W_2$$
$$= 6717 + 2558 = 9275 \text{ watts}$$

Power factor of the load is

$$\cos \Phi = \cos\left(\tan^{-1} \sqrt{3} \left(\frac{W_1 - W_2}{W_1 + W_2}\right)\right)$$

$$= \cos\left(\tan^{-1} \sqrt{3} \left(\frac{6717 - 2558}{9275}\right)\right)$$

$$\cos \Phi = 0.79$$

2. A three phase 500V motor load has a power factor of 0.4. Two wattmeters connected to measure the power show the input to be 30kW. Find the readings on each instrument.

Given:

$$V = 500V$$

$$\cos \Phi = 0.4$$

$$W_1 + W_2 = 30kW$$

Solution:

$$\tan\Phi = \sqrt{3}\ \frac{W_1 - W_2}{W_1 + W_2} \qquad \ldots(1)$$

The value of power factor is given as 0.4. Therefore, the value of Φ is

$$\Phi = \cos^{-1}(0.4) = 66.6^{o}$$

$$\tan\Phi = \tan 66.6^{o} = 2.311$$

Substituting the known values in equation (1), we get

$$W_1 - W_2 = 40kW \qquad \ldots(2)$$

The total power consumed is given as,

$$W_1 + W_2 = 30kW \qquad \ldots(3)$$

Solving equation (2) and (3), we get the individual readings as

$$W_1 = 35 \text{ kW and}$$

$$W_2 = -5 \text{ kW}$$

The negative sign in the second wattmeter indicates 'down scale'.

3. Two wattmeters connected to measure the input to a balanced three phase circuit indicate 2000W and 500W respectively. Find the power factor of the circuit (a) when both the readings are positive (b) when latter reading is obtained after reversing the connection to the current coil of one instrument.

Given:

$$W_1 = 2000 \text{ watts}$$

$$W_2 = 500 \text{ watts}$$

Solution:

(a) When both the readings are positive: Power factor of the circuit is

$$\cos\Phi = \cos\left(\tan^{-1}\sqrt{3}\left(\frac{W_1 - W_2}{W_1 + W_2}\right)\right)$$

$$= \cos\left(\tan^{-1}\sqrt{3}\left(\frac{2000 - 500}{2000 + 500}\right)\right)$$

$$\cos\Phi = 0.69$$

(b) When latter reading is obtained after reversing the connection:

$W_1 = 2000$ watts

$W_2 = -500$ watts

The formula now becomes,

$$\cos\Phi = \cos\left(\tan^{-1}\sqrt{3}\left(\frac{W_1 + W_2}{W_1 - W_2}\right)\right)$$

$$= \cos\left(\tan^{-1}\sqrt{3}\left(\frac{2000 + 500}{2000 - 500}\right)\right)$$

$$\cos\Phi = 0.327$$

11

Electromagnetics

[1]Mr. M. Sivaram Krishnan, [2]Dr. G. Emayavaramban,
[3]Mrs. M. Nivetha, [*4]Dr. M. Siva Ramkumar

[2-4]Assistant Professor Department of EEE, Faculty of Engineering,
Karpagam Academy of Higher Education
[1]Asistant Professor, Department of EEE, Karpagam College of Engineering,
*e-mail: sivaram0699@gmail.com

2.1 Magnetic Quantities

Magnetic Flux

The region around a permanent magnet or the space around a current carrying conductor occupied by the lines of force is called magnetic field.

The magnetic field is represented by imaginary lines of force known as magnetic flux. The unit of magnetic flux is Weber and is represented by the letter 'Φ'.

Properties of Magnetic flux

1. The magnetic flux lines are only imaginary lines.
2. Each line of magnetic flux forms a closed loop.
3. They do not intersect each other.
4. The magnetic flux which are parallel and in same direction repel one another.

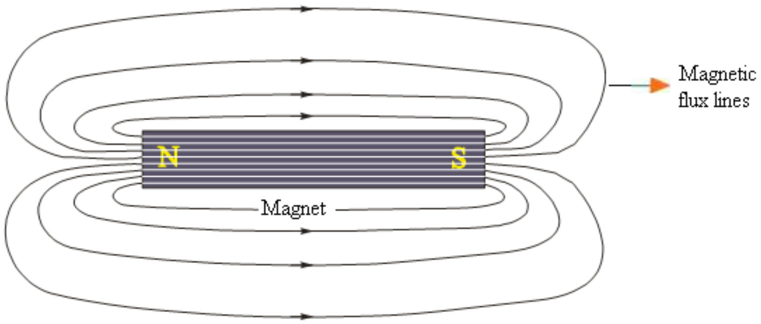


Fig. 2.1: Magnetic flux lines

Magnetic Flux Density

It is the magnetic flux per unit area. It is denoted by the letter 'B' and its unit is tesla (or) Weber/square meter.

$$B = \frac{\Phi}{A} \text{ Wb/m}^2$$

Magneto Motive Force

The force which establishes the magnetic flux in a magnetic circuit is called Magneto motive force (mmf). It corresponds to electro motive force (e.m.f) in an electric circuit.

The mmf is produced when a current passes through a coil of wire. The mmf is the product of the number of turns of the coil (N) and the current through the coil (I). The unit of mmf is Ampere - Turns (AT) and it is represented by the letter F.

mmf = NI Ampere-turns

Reluctance

It is the property of a material which opposes the establishment of magnetic flux in it. It is the resistance offered to the passage of magnetic flux through a material. It is represented by the letter 'S'. The unit of reluctance is AT/Wb.

$$S = \frac{mmf}{\Phi} = \frac{NI}{\Phi} \text{ AT / Wb}$$

The other formula for reluctance is,

$$S = \frac{l}{\mu A} = \frac{l}{\mu_o \mu_r A}$$

where,

l - Mean length of magnetic circuit in metre

μ_o - Absolute permeability of air = 4 x 10^{-7} Henry/meter

μ_r - Relative permeability of the magnetic material

A - Area of cross section of the magnetic circuit

Magnetic Field Strength

The magneto motive force per unit length of the magnetic circuit is termed as "Magnetic field intensity". It is denoted by the letter H and its unit is Ampere Turns/metre.

$$H = \frac{NI}{l} \ AT/m$$

where,

N - No. of turns of the coil

I - current through the coil in Amperes

l - length of the magnetic circuit in metres

2.2 Force on a Current Carrying Conductor in a Magnetic Field (Magnetic Force)

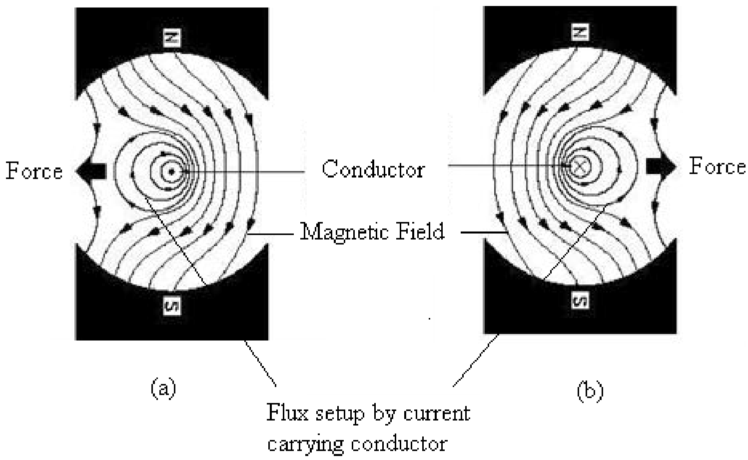


Fig. 2.2: Force on a Current Carrying Conductor in a Magnetic Field

Fig. 2.2 show the current carrying conductor placed in a magnetic field. When current flows through a conductor, it establishes a magnetic field in clockwise direction around the conductor.

When the external field is in vertically downward direction, the field of the conductor aids the same direction external field on the right side of the conductor and opposes the external field on the left hand side of the conductor. Due to this effect a force is produced which pushes the conductor of the left.

If the direction of current is reversed as in Fig. 2.2 (b), the flux around the conductor is in counter – clockwise direction and the resulting force pushes the conductor to the right.

The magnitude of force is given by,

$$F = BIl \text{ Newton}$$

where,

B - Flux density in Wb/m^2

I - Current in ampere

l - Length of conductor in metre

If the conductor is inclined by an angle θ to the magnetic field, then force (F) is given by

$$F = BIl \sin\theta$$

If the coil has N turns, the force is

$$F = BIlN \text{ Newton}$$

Since the force is acting at a radius 'r' metre, the torque on the coil is

$$T = BIlNr \text{ Newton-metre}$$

2.3 Faraday's Laws of Electromagnetic Induction

First Law

It states that, "if the flux linking a conductor changes, an emf is induced in it".

Second Law

It states that, "the magnitude of induced emf in a coil is equal to the rate of change of flux linkage".

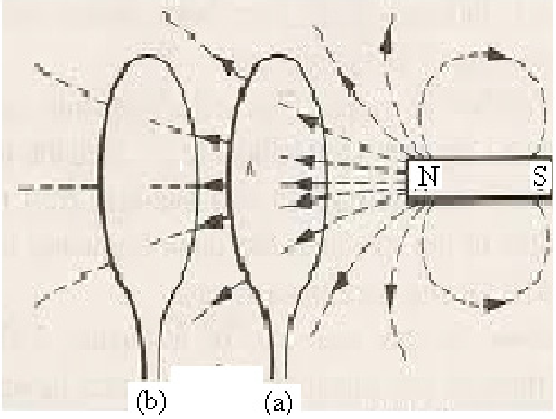


Fig. 2.3: Motion of Conductor with respect to Magnetic field

The position (b) of the above figure shows a coil having 'N' turns and let the flux linking with the coil be Φ_1 at time t_1.

When the coil is moved to a small distance closer to the magnetic field (position (a)), the flux linking with the coil increases and is Φ_2 at time t_2.

Therefore,

Initial flux linkage = $N\Phi_1$

Final flux linkage = $N\Phi_2$

Hence,

$$\text{Induced emf, } e = \frac{\Phi_2 - N\Phi_1}{t_2 - t_1} = \frac{N(\Phi_2 - \Phi_1)}{t_2 - t_1}$$

$$e = N\frac{d\Phi}{dt}$$

where,

$$d\Phi = (\Phi_2 - \Phi_1)$$

$$dt = t_2 - t_1$$

The direction of induced emf is opposite to the cause producing it (Lenz's law).

Therefore,

$$e = -N\frac{d\Phi}{dt}$$

2.4 Lenz's Law

Lenz's law gives the direction of induced current set up due to electromagnetic induction. It states that an induced current will flow in such a direction so as to oppose the cause that produces it. The cause that produces the current is change of flux linkage in the coil.

2.5 Fleming's Right Hand Rule

The direction of the dynamically induced emf or current can be determined by using "Fleming's Right hand rule".

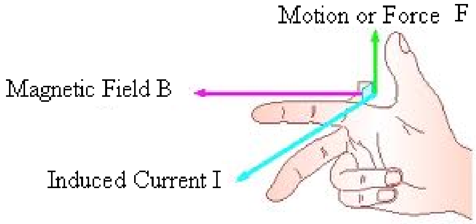


Fig. 2.4: Fleming's Right hand rule

Thumb - Direction of motion of the conductor

Fore finger - Direction of magnetic flux

Middle finger - Direction of induced emf [or] current

2.6 Fleming's Left Hand Rule

The direction of rotation of any motor can be found by applying Fleming's left hand.

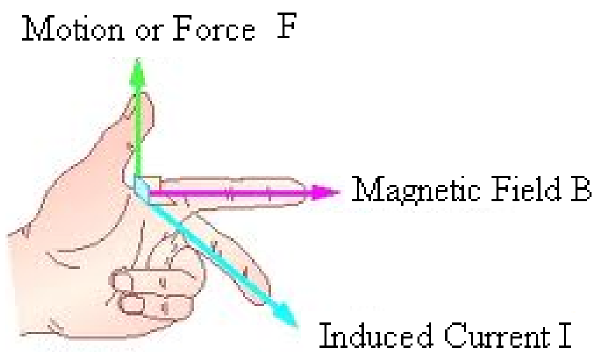


Fig. 2.5: Fleming's Left hand rule

2.7 Types of Induced EMF

The emf induced by the electromagnetic induction is classified into the following two types.

1. Statically induced emf
2. Dynamically induced emf

1. Statically induced EMF

When the conductor is stationary and the magnetic field is moving around the conductor, an emf is induced in the conductor and is called statically induced emf.

It is subdivided into

a) Self induced emf

b) Mutually induced emf

a) Self Induced EMF

The emf induced in a coil due to the change of its own flux linked with it is called self induced emf.

Whenever current flows through the coil a magnetic field is produced. By varying the resistance in the circuit using rheostat, the current flowing through the coil varies and hence flux linking the coil also varies (Fig.2.6). Hence by Faraday's laws an emf is induced in the coil. The magnitude of this self induced emf is given by,

$$e = -N\frac{d\Phi}{dt}$$

where,

N - number of turns of the coil

$\frac{d\Phi}{dt}$ - Change in flux with respect to time dt

The negative sign indicates that the direction of induced emf is always such as to oppose the cause producing them (Lenz's law).

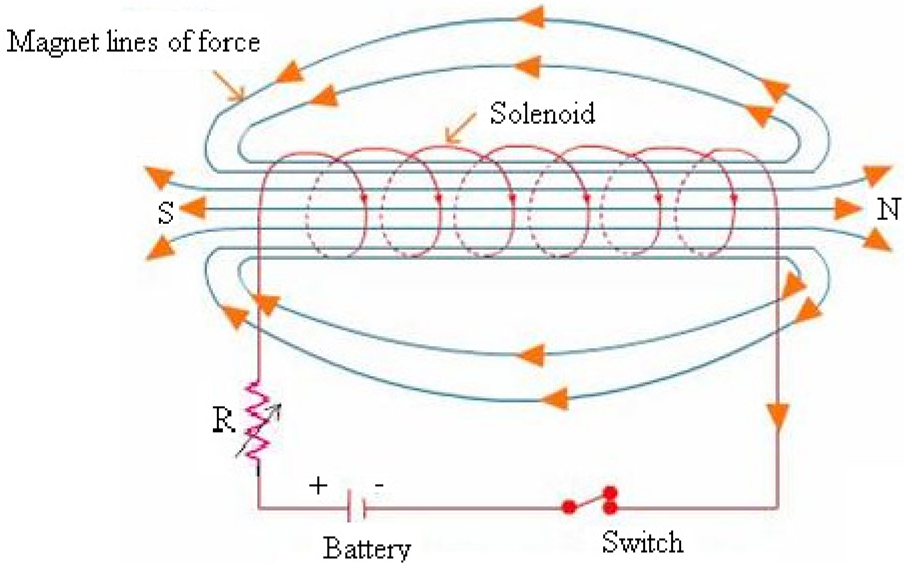


Fig. 2.6: Field lines of the magnetic field through and around a current carrying solenoid

Self inductance: When the current in a coil changes an emf is induced in it, which opposes the change of current in the coil. This property of the coil is called its self inductance or inductance.

We know that,

$$\text{Self induced emf, } e = -N\frac{d\Phi}{dt} \quad \text{Volts} \qquad \ldots(2.1)$$

The rate of change of flux depends upon the rate of change of current. Therefore self induced emf may also be expressed as

$$e \propto -\frac{di}{dt}$$

$$e = -L\frac{d\Phi}{dt} \qquad \ldots(2.2)$$

where, L is a constant.

Equating (2.1) and (2.2)

$$N\frac{d\Phi}{dt} = L\frac{di}{dt}$$

$$N\, d\Phi = L\, di$$

$$N\,\Phi = L\,i$$

$$L = \frac{N\,\Phi}{i} \text{ Henry} \qquad \ldots(2.3)$$

where, L is called inductance of the coil and its unit is Henry.

We know that,

$$\Phi = \frac{\text{mmf}}{\text{Reluctance}}$$

Substituting the formulae for mmf and reluctance as

$$\text{mmf} = NI$$

$$\text{Reluctance} = \frac{l}{\mu\, A}$$

Flux Φ becomes,

$$\Phi = \frac{\mu\, A\, NI}{l}$$

Therefore equation (3) can be written as,

$$L = \frac{N\,\mu\, A\, NI}{I} = \frac{N^2 \mu\, A\, I}{l\, I} \text{ Henry} \qquad \ldots(2.4)$$

Mutually induced EMF: The emf induced in a coil due to the changing current in the neighbouring coil is called mutually induced emf.

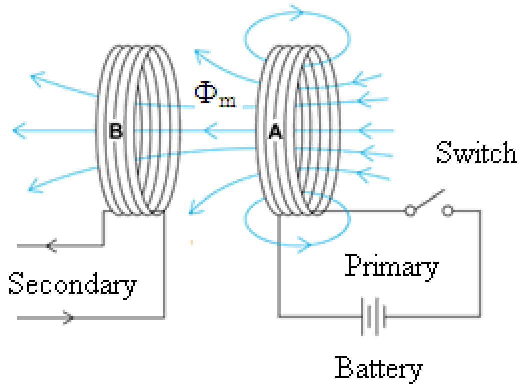


Fig. 2.7 Mutually Induced Emf

The change in flux in coil A when links with coil B induces an emf in coil B due to mutual induction. The flux produced becomes common to both coil A and B and hence it is known as mutual flux. The emf induced in coil A is called self induced emf and the emf induced in coil B is called mutually induced emf.

Mutual inductance: It is the ability of one coil to produce an emf in a near by coil by induction, when the current in the first coil changes.

The mutual induced emf in coil B is, $e_m = -N_B \dfrac{d\Phi_m}{dt}$ …(2.5)

where, Φ_m is the Mutual Flux

It can be also expressed as, $e_m = -M \dfrac{dI_A}{dt}$ …(2.6)

Equating (2.5) and (2.6),

$$N_B\,(d\Phi_m) = M\,(d\,I_A)$$

$$N_B\,\Phi_m = M\,I_A$$

Therefore, $M = \dfrac{N_B\,\Phi_m}{I_A}$ Henry …(2.7)

Substituting, $\Phi_m = \dfrac{\mu\,A\,N_A\,I_A}{l}$ in Equation (2.7)

$$M = \frac{N_A N_B\,\mu\,A}{l}\ \text{Henry} \quad \text{…(2.8)}$$

Dynamically induced EMF: When a conductor moves in a stationary magnetic field so as to cut the magnetic flux, an emf is induced in that conductor.

Since the emf induced in the conductor is due to its motion with respect to field it is known as dynamically induced emf.

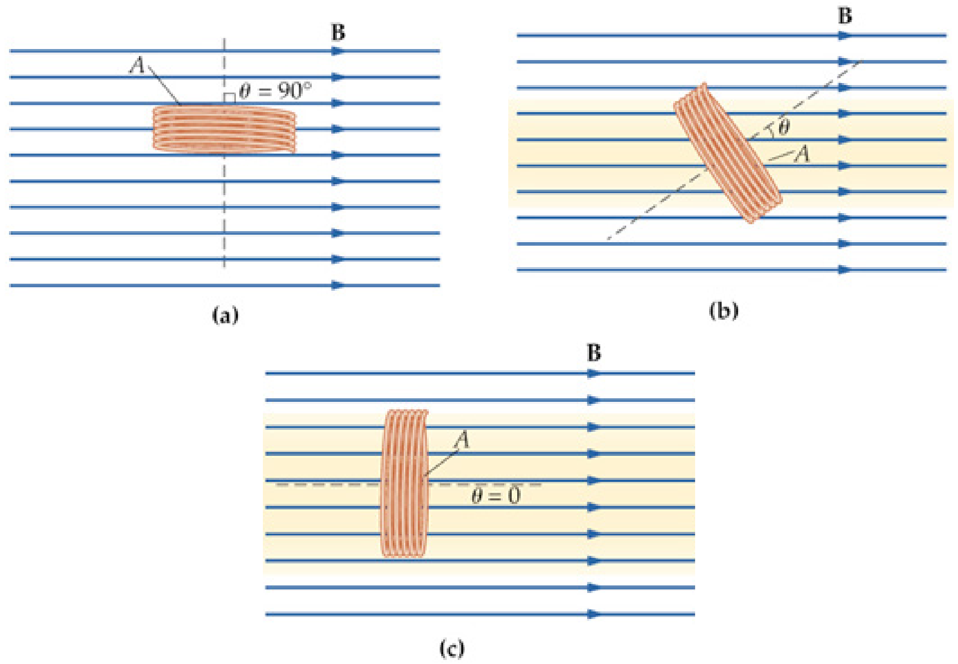


Fig. 2.8: Motion of the conductor in the magnetic field

Consider a conductor 'l' metre long moving at a velocity 'v' m/s in a uniform magnetic field of density B Wb/m^2 as shown in Fig.2.8.

(a) Conductor perpendicular to magnetic field:

$$e = Blv \sin\theta \text{ (equation for (b))}$$
$$= Blv \sin 90^o$$
$$e = Blv \text{ volts}$$

(b) Conductor parallel to magnetic field:

$$e = Blv \sin 0^o$$
$$e = 0 \text{ volts}$$

PROBLEM:

A conductor of length 0.5m situated in and at right angles to an uniform magnetic field of flux density 1 Wb/m^2 moves with a velocity of 40 m/sec. Calculate the emf induced in the conductor. What will be the emf induced, if the conductor moves at an angle of 60° to the field and then moves parallel to the magnetic field.

SOLUTION:

Given data:

$$l = 0.5\text{m}$$

$$B = 1\text{Wb/m}^2$$

$$v = 40 \text{ m/sec}$$

Formula: Emf induced in the conductor is given by

$$e = Blv \sin\theta$$

a) emf when conductor moves right angles to the magnetic field

here, $\theta = 90^o$

$$e = Blv \sin\theta$$
$$= Blv \sin 90^o$$
$$e = Blv \times 1$$
$$= 1 \times 0.5 \times 40$$
$$= 20 \text{ V}$$

b) emf induced when the conductor moves at an angle 60^o to the field.

here, $\theta = 60^o$

$$e = Blv \sin\theta$$
$$= Blv \sin 60^o$$
$$e = 1 \times 0.5 \times 40 \times 0.866$$
$$= 17.32 \text{ V}$$

c) emf induced when the conductor moves parallel to the magnetic field.

here, $\theta = 0^o$

$$e = Blv \sin\theta$$
$$= Blv \sin 0^o$$
$$e = 1 \times 0.5 \times 40 \times 0$$
$$= 0 \text{ V}$$

2.8 Energy Stored in a Magnetic Field

To produce a magnetic field around a coil, energy is needed. Through no energy is needed to maintain it, this energy is stored in the magnetic field and is not used up. When the current is decreased this stored energy is returned to the circuit.

The emf induced across 'L' is given by

$$e = L\frac{di}{dt}$$

Therefore, instantaneous power, P = e. i

$$= Li\frac{di}{dt}$$

The energy (dw) put into the magnetic field during a short interval of time (dt) is

Energy = Power x Time

$$dW = Li\frac{di}{dt} \times dt$$

$$= Li\ di$$

$$W = \int_0^I Li\ di = L[i^2/2]_0^I$$

$$W = \frac{1}{2}LI^2 \quad \text{Joules}$$

Therefore, energy stored in a magnetic field is $= \frac{1}{2}LI^2$ Joules

2.9 Magnetic Hysteresis and Hysteresis Loop

When a magnetic material is subjected to a cycle of magnetism (i.e. it is magnetized first in one direction and then in the other), it is found that flux density B in the material lags behind the applied magnetizing force H. This phenomenon is known as hysteresis.

Hysteresis Loop

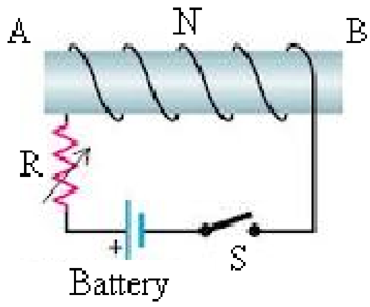


Fig. 2.9: Magnetizing circuit with an alternating mmf

Consider an unmagnetized iron bar AB wound with N number of turns as shown in Fig.2.9. The magnetizing force can be varied by varying the current through the coil.

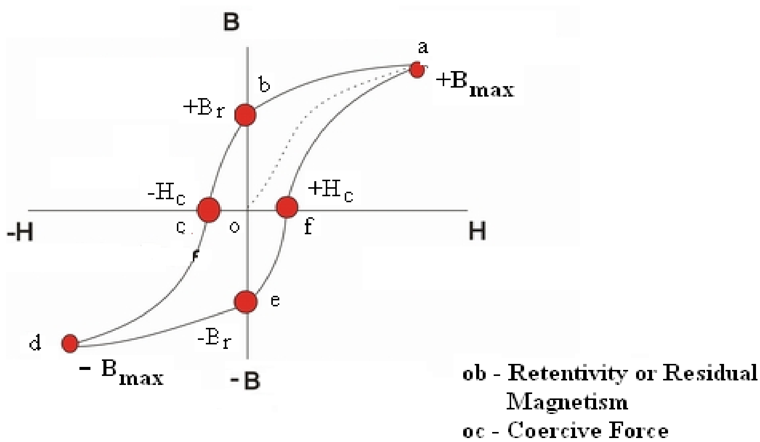


Fig. 2.10: B – H Curve

When the iron piece is subjected to one cycle of magnetization, the resultant B – H curve 'abcdefa' loop is obtained as shown in Fig. 2.10. This loop is called Hysteresis loop.

When current in the coil is zero, H = 0 and hence B is also zero, (since $B = \mu H$). As H is increased (by increasing the current) the flux density also increases until the point of maximum flux density ($+ B_{max}$) is reached. The material is saturated and beyond this point the flux density will not increase for further increase of H. The flux density remains at its maximum value ($+ B_{max}$).

Now H is gradually reduced (by reducing the current) it is found that, the flux density (B) does not decrease along 'oa', but follow the path 'ab'. At point b, H is zero, but the flux density is $+B_r$ called **residual flux** or **retentivity** of the material.

To remove the residual magnetism the magnetizing force H is reversed by reversing current through the coil. When H is increased in the reverse direction, such that H = OC, the BH curve follows the path 'bc'. Now the residual magnetism is zero. The value H= OC is called **coercive force** (-HC).

If H is further increased in negative direction, the material again saturates (point d) in the negative direction. Reducing H to zero and then increasing it in the positive direction completes the curve 'defa'.

Thus when can iron piece is subjected to one cycle of magnetization, the BH curve traces a closed loop 'abcdefa' called **Hysteresis loop**.

During the reversal magnetization, molecular friction takes place in the inner molecular material and produces heat. This energy loss in the form of heat is proportional to the area of the hysteresis loop.

2.10 Biot - Savart Law

The Biot-Savart Law provides us with a way to find the magnetic field at an empty point in space, due to current in the wire. The idea behind the Biot-Savart Law is that each infinitesimal element of the current-carrying wire makes an infinitesimal contribution to the magnetic field at the empty point in space. Once you find each contribution, all you have to do is add them all up.

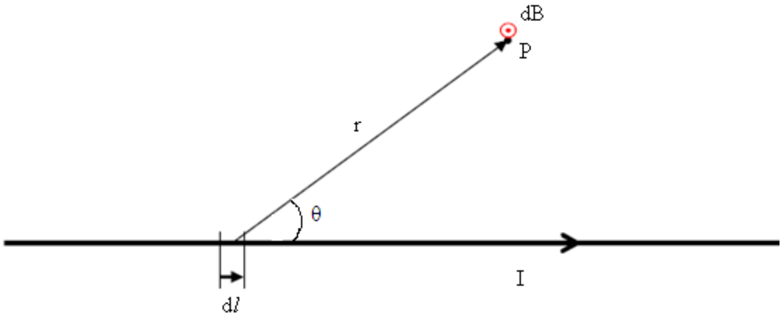


Fig. 2.11: Biot - Savart Law

Consider a conductor element d*l* carrying a current I. Let P be the point at which we want to find the flux density. The point is situated at a distance 'r' from the element d*l* inclined at an angle θ to the element.

Therefore, according to Biot-Savart's law

$$dB = \frac{\mu I \, dl \sin\theta}{4\pi r^2}$$

$$B = \frac{\mu I}{4\pi} \int \frac{\sin\theta \; dl}{r^2}$$

where,

B – flux density at P, Tesla

μ – permeability of medium, Hm^{-1}

d*l* – length of current element, m

I – current in the conductor, A

r – distance from element to P, m

The integration is carried out over the length of the conductor. The above two equations are said to be statement of Biot-Savart law.

For an infinite conductor (conductor whose length is infinite),

$$B = \frac{\mu I}{2 \pi r}$$

Thus the Biot-Savart Law represents a powerful straightforward method of calculating the magnetic field due to a current distribution.

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Transmission Line Fault Analysis and Classification Using PSCAD/EMTDC

[1]Dr. G. Radhika, [2]Dr. M. Suryakalavathi, [3]D. Nagendra Prasanna

[1]Senior Assistant Professor, Dept. of EEE, VNR VJIET, Hyderabad, India, radhika_g@vnrvjiet.in
[2]Professor, Dept. of EEE, VNR VJIET, Hyderabad, India, mungala@yahoo.com
[3]Senior Software Engineer, Indian Software Development Lab, Hyderabad, India, dnprasanna@gmail.com

ABSTRACT

In a normal operation of power systems, the most common faults will always leads to disruption of electrical power supply to the consumers. The system thus deviates from the normal conditions, always gives rise to surge magnitudes i.e higher than normal value. For safety of the electrical equipment, short circuited faults are to be addressed first, as they are considered to be the characteristics of transient disturbances. With the application of evolutionary programming tools, discernment among different types of transmission line faults can be achieved. Thus, Power systems CAD (PSCAD) software is used to design and simulate electrical power systems. This PSCAD/EMTDC software is most widely used for simulating different faulty and normal conditions on HV transmission lines, like L-G, L-L, D-L-G and 3-ϕ short circuits. The voltage and current variations were examined during short circuit faults, with and without fault impedances as well as with respect to distance from fault location. In this paper, wavelet transforms was also applied to excerpt information from transient signals and also at the same time both in time and frequency domain, used to determine whether the transients are due to disturbances or faults from the data obtained from the fault analysis.

Keywords: Transmission Line, Faults, PSCAD/EMTDC, Wavelet, Fault Resistance.

I. Introduction

A. Introduction to Faults

Faults are defined as flow of large current which is due to undesirable and inevitable events which could temporarily disturb the power system stability condition if there is a insulation failure at any part of the system. If any conducting object comes in contact with power conductor a fault or short circuit occurs. There are many causes for the fault occurrence, such as lightning, wind damage, trees falling across the transmission lines, birds shorting lines, etc. In order to provide system protection, it is necessary to study a power system under fault conditions. This paper focuses on causes and analysis of the faults in transmission lines. A comparative analysis was also performed to compare the calculated results and with the results obtained in the implemented methods. There are two kinds of faults which can happen on any transmission lines. They are symmetrical and asymmetrical faults which are otherwise called balanced and unbalanced faults individually. The faults that happen on the power system are mostly unsymmetrical. Notwithstanding this power system faults might be sorted as series and shunt faults, where series faults happen to be in line impedance, neither includes neutral or ground nor any interconnection between the phases. The as often as possible happening sort of shunt fault is LG faults. Shunt faults are the unbalanced between phases or amongst phases and ground. In shunt faults, the faulty phase voltage and frequency would decline while there is increment of current.[6]

B. Introduction to Wavelets

Wavelets are scientific functions that cut up information into various frequencies parts, and afterward contemplate every component with a determination coordinated to its scale. A series of wavelet is a general representation of a square integrable function by means of few orthonormal series being generated by a wavelets. The essential means behind wavelet transforms is, transformation shall allow changes in time extension only, but not in shape which can be done by means of selecting suitable basic functions which permits this. With the changes in time extension were probable to confirm the consistent analysis frequency of basic function. In functional and numerical analysis, discrete wavelet transform is a wavelet transform to which the wavelets were discretely sampled. While compared to wavelet transforms, the important advantage over fourier transforms is its temporal resolution, also captures both location and frequency information.[4] A continuous wavelet transform (CWT) is used to divide a continuous-time function into wavelets. CWT holds the property to build a time-frequency representation of a signal which offers a very good frequency and time localization. In case of functional and numerical analysis, DWT is defined as a wavelet transform to which the wavelets were individually sampled. While compared to other wavelet transforms, the crucial advantage over Fourier transforms is temporal resolution which means it captures both location and frequency information.[7]

II. Modelling of Transmission Line

Transmission lines in power system are nonlinear in nature, due principally to the frequency reliance of conductors (skin impact), and also the ground or earth return way. The capacity to represent the system precisely and effectively has a basic impact in the electromagnetic transient simulation of power system. Bergeron models are used to model the transmission line that is to be simulated for fault analysis. The Bergeron Model is an extremely basic, steady frequency model based on travelling waves. This model speaks to system L and C in a distributed way while the aggregate system protection R is lumped.

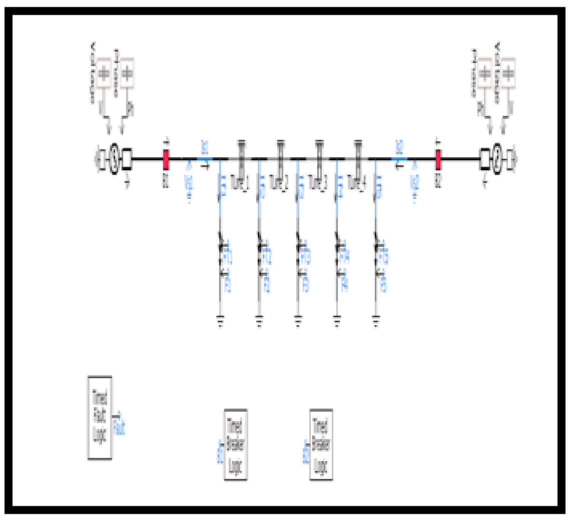

Fig. 1: Transmission line modeled for conducting fault analysis study

Figure 1 represents the transmission line modelled for conducting the fault analysis study. A transmission line of length 100 Km between two and three phase voltage sources acting as substations is considered in this modeling. For every 25 Km of length, a transmission tower is placed. The conductors used are Chukar conductors. Breakers are placed at the substations to interrupt the faults. To study the changes in fault currents and voltages due to variation of fault distance and fault resistance, faults are applied at a distance of 25 Km from one another for a length of 100 Km. Timed fault logic is placed to control the fault timings. Timed breaker logic controls the operation of breaker according to the instruction given by operator.

III. Simulation of Transmission Line for Fault Analysis[3]

The transmission line voltage is 220 kV. Timed Fault Logic is used to control the faults from where external control is given to Fault Control Panel. Application of faults at different locations, start time of fault, duration of fault, type of fault is controlled by Fault Control Panel. Breakers interrupt the fault currents at given open time. The breaker is closed at given close time. The fault resistance is varied in steps and all types of faults at different fault locations are applied to study the faults. Fig. 2 and Fig.3 depicts pre fault voltage and current waveforms under steady state conditions. When fault is created at 0.2 secs with varying fault resistance at different locations, here in Fig. 4 and Fig. 5 depicts the fault current without breaker action and with. In this paper, the simulation model is considered of 100 Km, so at regular intervals fault was created and Fig. 6, 7,8, 9, 10 depicts the fault currents respectively. The breaker opens at 0.25 seconds and interrupts the fault current. The breaker closes at 0.5 seconds and the fault is cleared.

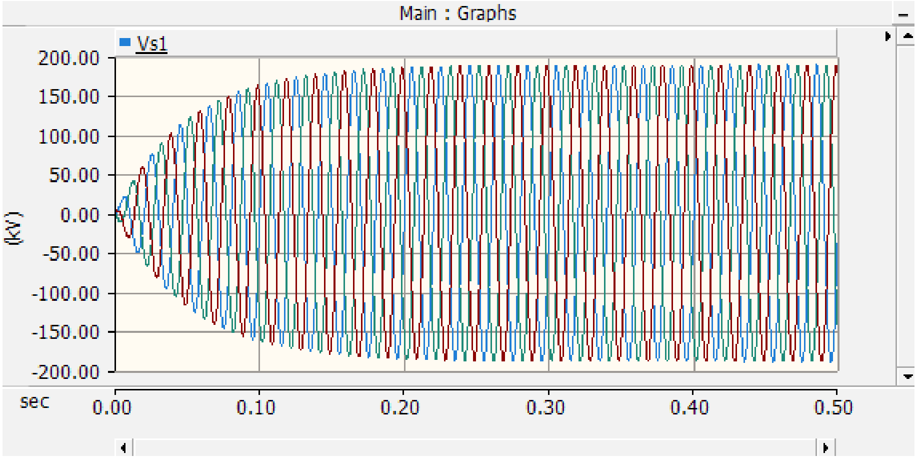

Fig. 2: Voltage waveform at pre fault condition

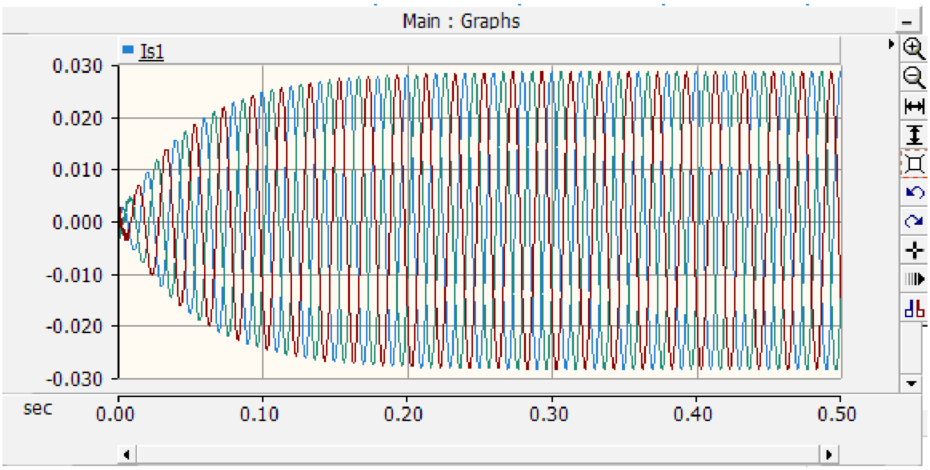

Fig. 3: Current waveform at pre fault condition

The LG fault is applied at 0.2 seconds and the duration is 0.2 seconds. The breaker opens at 0.25 seconds and closes at 0.4 seconds.

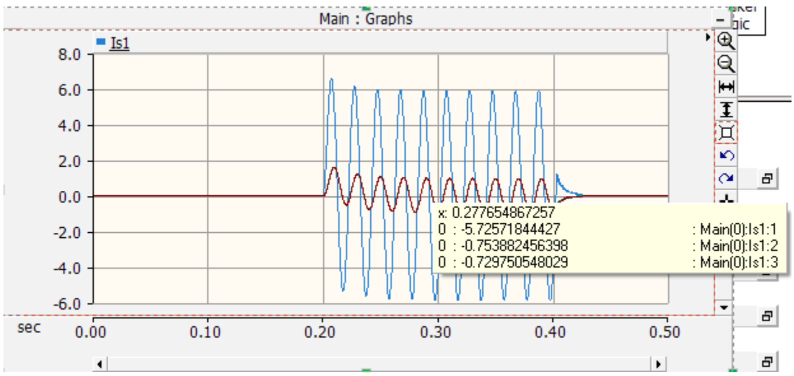

Fig. 4: Fault current waveform without breaker action

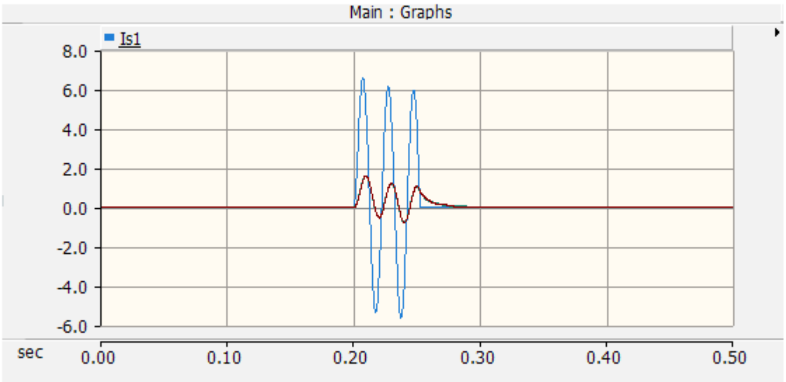

Fig. 5: Fault current waveform with breaker action

The faults are applied at different fault locations and the results are analyzed. The results of LG fault at different fault locations at fault resistance 0 ohms is as below.

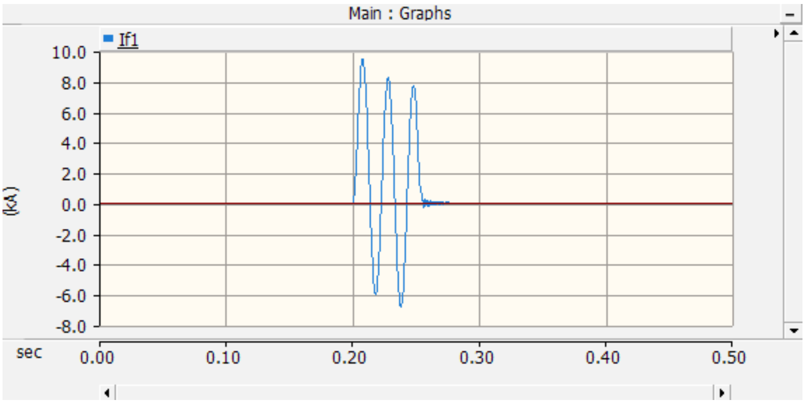

Fig. 6: Fault curreent waveform at location 1 (0 km)

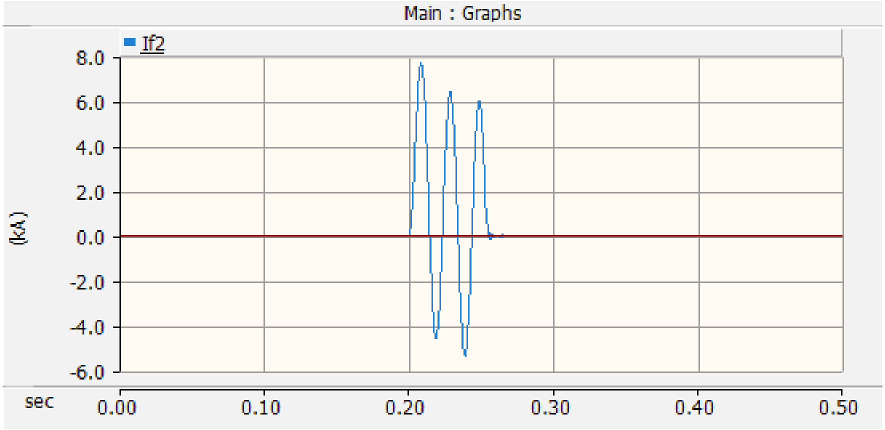

Fig. 7: Fault current waveform at location 2 (25 km)

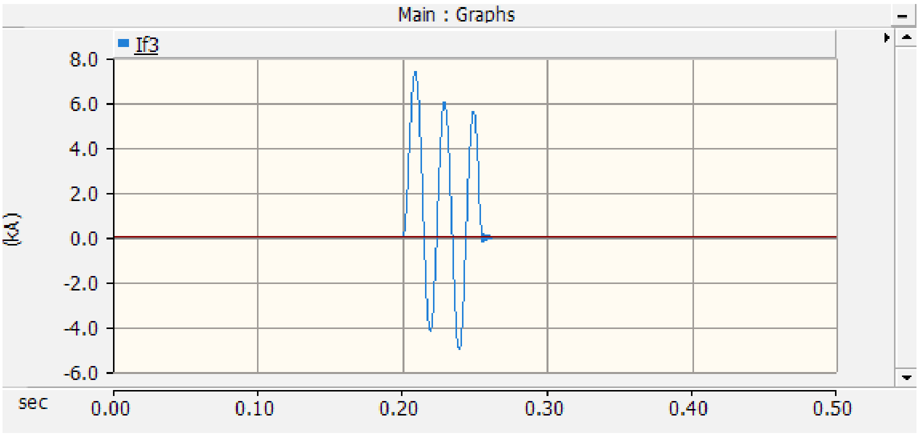

Fig. 8: Fault current waveform at location 3 (50 km)

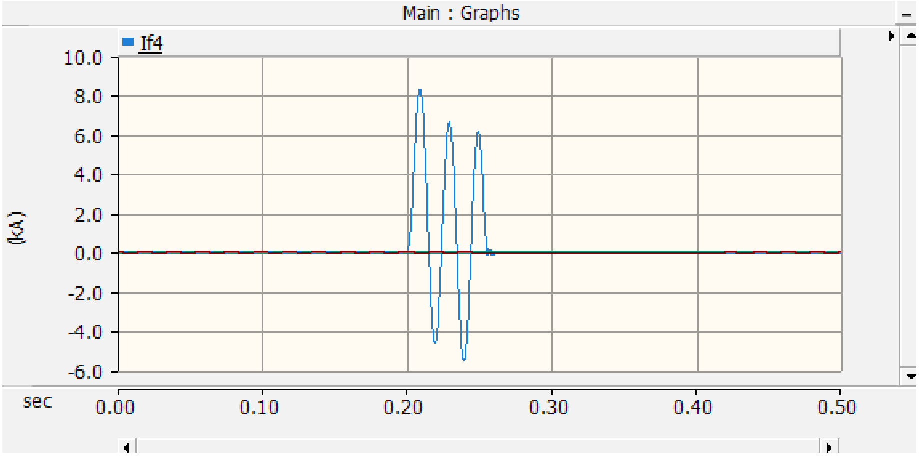

Fig. 9: Fault current waveform at location 4 (75 km)

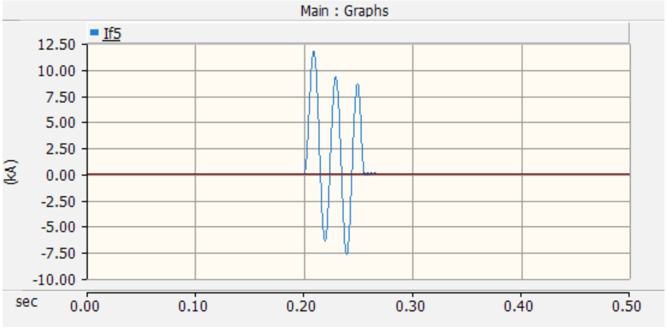

Fig. 10: Fault current waveform at location 4 (100 km)

In similar way, LL fault, LLG Fault, LLL fault are also analyzed at 0 ohms. The faults are analyzed at 25 ohms and 50 ohms also and the values are tabulated below in Table 1, Table 2 and Table.3.Below table shows, (i) as the distance of the fault from the source increases the fault current magnitudes decrease because as distance increases, the impedance increases, (ii) The increase in fault resistance makes a decrease in the fault current magnitude. As per Ohms law, current is inversely proportional to resistance, (iii) L-G fault is severe fault at the source but as distance of fault location increases from the source LLL fault becomes severe.

Table 1: Fault Current for resistance at 0 ohms

FAULT DISTANCE	FAULT TYPE	CURRENT FROM SOURCE A			CURRENT FROM SOURCE B		
		IA	IB	IC	IA	IB	IC
0KM	L-G	6.55	1.58	1.58	3.21	0.75	0.77
	L-L	3.02	3.02	0.02	2.64	1.04	0.025
	L-L-G	7.04	8.33	2.48	3.21	1.77	1.63
	L-L-L-G	3.49	3.49	3.49	2.17	1.53	1.53
25KM	L-G	4.34	0.85	0.87	3.45	0.36	0.36
	L-L	2.73	2.67	0.02	2.33	1.609	0.02
	L-L-G	3.32	4.51	0.83	3.58	1.89	0.46
	L-L-L-G	3.07	3.07	3.07	2.43	1.77	1.78
50KM	L-G	3.2	0.5	0.5	4.16	0.26	0.22
	L-L	2.38	2.36	0.028	2.29	1.86	0.02
	L-L-G	2.75	3.19	0.45	3.23	2.27	0.22
	L-L-L-G	2.72	2.72	2.72	2.74	2.33	2.33
75KM	L-G	2.73	0.56	0.59	5.64	0.47	0.43
	L-L	2.11	2.11	0.02	3.01	2.21	0.02
	L-L-G	2.52	2.69	0.59	4.22	3.08	0.49
	L-L-L-G	2.43	2.43	2.43	3.14	2.64	2.64
100KM	L-G	2.47	1.027	1.043	7.24	1.07	1.04
	L-L	1.89	1.89	0.02	3.14	2.75	0.018
	L-L-G	2.1	2.1	1.9	8.48	7.56	2.16
	L-L-L-G	2.16	2.16	2.16	3.7	3.31	3.31

Table 2: Fault Current for resistance at 25 ohms

FAULT DISTANCE	FAULT TYPE	CURRENT FROM SOURCE A			CURRENT FROM SOURCE B		
		IA	IB	IC	IA	IB	IC
0KM	L-G	3.08	0.71	0.69	1.42	0.49	0.53
	L-L	2.43	2.51	0.02	1.87	1.26	0.02
	L-L-G	3.06	3.29	0.8	1.63	0.87	0.67
	L-L-L-G	2.27	3.31	2.33	1.74	1.26	1.26
25KM	L-G	2.45	0.43	0.43	1.76	0.27	0.3
	L-L	2.22	2.3	0.02	2.11	1.43	0.02
	L-L-G	2.05	2.91	0.46	1.94	1.27	0.31
	L-L-L-G	2.06	2.5	2.08	1.96	1.47	1.47
50KM	L-G	1.95	0.26	0.3	2.2	0.20	0.17
	L-L	2	2.03	0.028	2.39	1.78	0.02
	L-L-G	1.72	2.2	0.27	2.32	1.61	0.19
	L-L-L-G	1.91	1.92	1.95	2.2	1.78	1.73
75KM	L-G	1.57	0.33	0.38	2.83	0.33	0.29
	L-L	1.8	1.84	0.02	2.73	2.08	0.02
	L-L-G	1.57	1.74	0.36	2.92	2.22	0.28
	L-L-L-G	1.71	1.72	1.72	2.5	2.29	2.05
100KM	L-G	1.26	0.59	0.64	3.82	0.6	0.54
	L-L	1.61	1.63	0.02	3.11	2.54	0.02
	L-L-G	1.5	1.24	0.77	4.21	2.94	0.68
	L-L-L-G	1.525	1.53	1.55	2.79	3.4	2.5

Table 3: Fault Current for resistance at 50 ohms

FAULT DISTANCE	FAULT TYPE	CURRENT FROM SOURCE A			CURRENT FROM SOURCE B		
		IA	IB	IC	IA	IB	IC
0KM	L-G	2.12	0.45	0.43	0.9	0.31	0.35
	L-L	2	2.12	0.02	1.46	1.07	0.02
	L-L-G	1.93	2.31	0.51	1.08	0.76	0.39
	L-L-L-G	1.62	2.03	1.66	1.17	0.91	0.91
25KM	L-G	1.7	0.28	0.26	1.15	0.18	0.21
	L-L	1.83	1.99	0.02	1.63	1.25	0.02
	L-L-G	1.47	1.83	0.33	1.31	0.91	0.21
	L-L-L-G	1.52	1.62	1.54	1.32	1.06	1.05
50KM	L-G	1.36	0.17	0.2	1.46	0.12	0.11
	L-L	1.63	1.8	0.02	1.84	1.43	0.02
	L-L-G	1.25	1.5	0.18	1.57	1.2	0.12
	L-L-L-G	1.37	1.39	1.4	1.46	1.27	1.25
75KM	L-G	1.06	0.21	0.26	1.86	0.22	0.18
	L-L	1.47	1.71	0.02	2.1	1.72	0.02
	L-L-G	1.06	1.2	0.22	1.91	1.55	0.20
	L-L-L-G	1.21	1.21	1.24	1.67	1.63	1.43
100KM	L-G	0.8	0.41	0.36	2.39	0.4	0.35
	L-L	1.31	1.64	0.02	2.35	2.1	0.02
	L-L-G	1.01	0.87	0.42	2.56	1.93	0.42
	L-L-L-G	1.04	1.04	1.07	2.23	2.23	1.84

IV. Classification of Faults

By using the above plotted graphs, fault classification is done by wavelet decomposition and fault classification algorithm.

A. Interfacing PSCAD with MATLAB

The data of the faulted current waveform graphs is copied into notepad and imported in MATLAB and saved as mat files.

B. Wavelet Decomposition[1]

Wavelet Packet Decomposition (WPD) is also known as Optimal Sub band Tree Structuring which is a wavelet transform. While discrete-time (sampled) signal are passed through more number of filters. In the DWT, calculation at each level is done by passing the last wavelet approximation coefficients (cA_j) by means of discrete-time LP & HP quadrature mirror filters. To create full binary tree in the WPD, both the detail (cD_j (in the 1-D case), cH_j, cV_j, cD_j (in the 2-D case)) and approximation coefficients need to be decomposed. For n number of levels of decomposition, for given as opposed to (3n + 1) sets for the DWT, the WPD produces 2^n different sets of coefficients. Due to the down sampling process, overall count of coefficients remains still the same and there is no dismissal. From compression point of view, standard wavelet transform might not produces the best results as it is limited to wavelet bases which would be increased by a power of 2 towards the low frequencies. For a particular signal, it can be another combination of bases which produces more necessary representation for a given particular signal. Fig.11 depicts wavelet decomposition for single phase signal. This is representation of three level decomposition. The signal is passed through low pass filter and high pass filter and then down sampled. The output of first level decomposition is one approximation coefficient and one detailing coefficient. The result of first level decomposition is again decomposed for different levels.

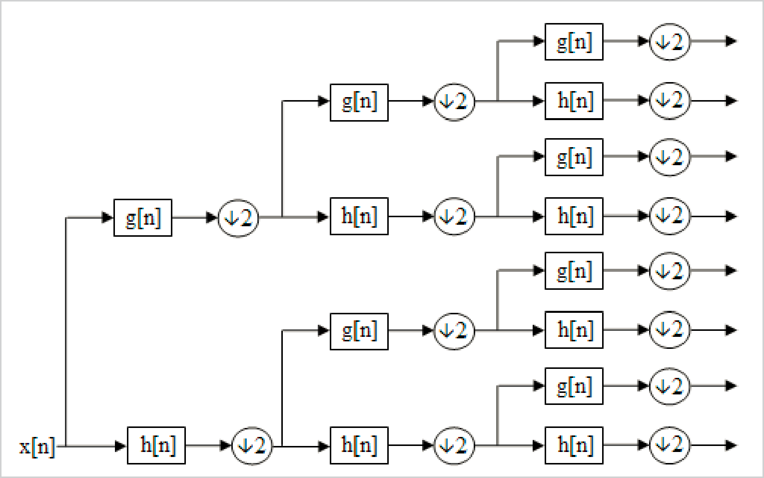

Fig. 11: Wavelength Decomposition for single phase

The three phase fault current waveform I_{abc} is taken and wavelet decomposition is separately applied for each phase. Each phase current wave is passed through low pass filter (LPF) and a high pass filter (HPF). After passing through filter, the wave is down sampled and gives approximation co-efficient and detailing co-efficient Thus it completes one level of decomposition. Three level wavelet decomposition is not sufficient to classify all the faults, so the decomposition is done for five levels. In the below Fig. 12, the wavelet decomposition is shown for three levels. The same procedure is carried out for five level decomposition.

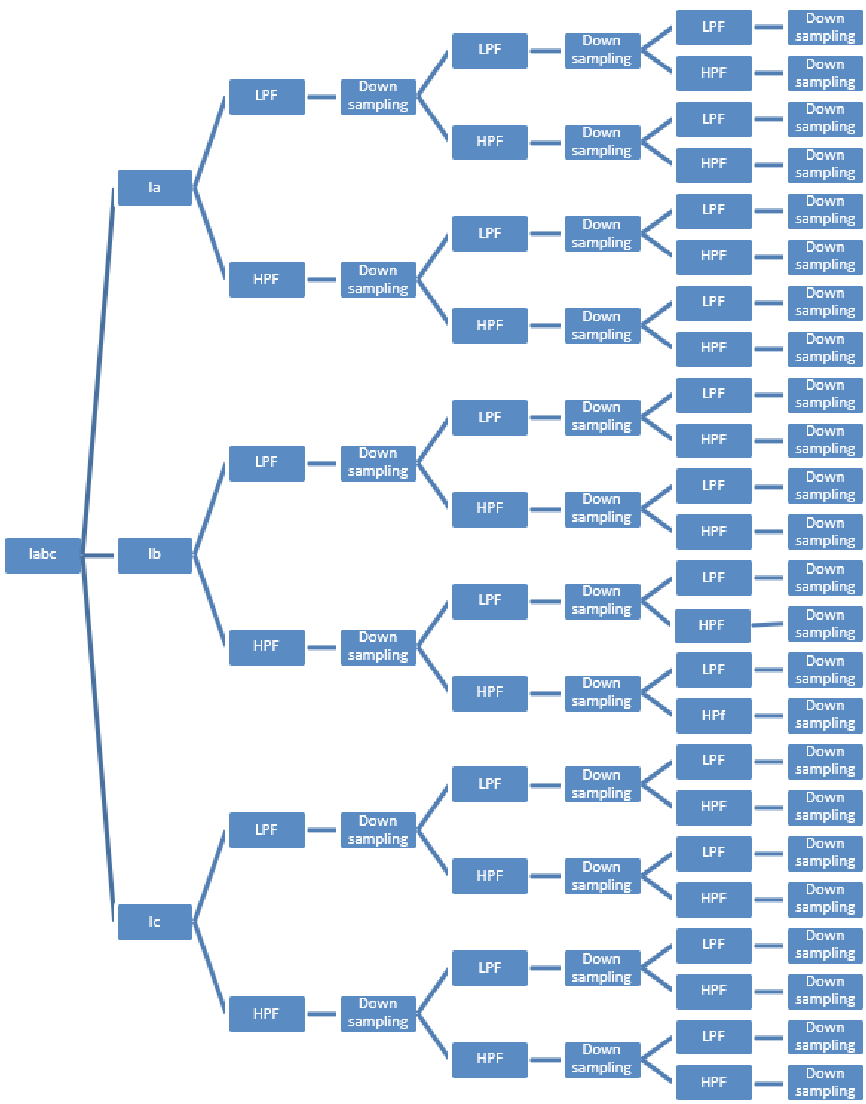

Fig. 12: Wavelength Decomposition for 3 phase

In this paper, DWT is utilized for fault discovery reason because of following reasons. It gives a quick, dependable, precise fault examination and it likewise less demanding to actualize and it gives less calculation time and assets required contrasted with the persistent wavelet transform. The three-phase current signal of transmission line is taken as information and decayed utilizing discrete wavelet change to acquire include extraction. The highlights extricated by handling discrete wavelet transforms are greatest and least detail coefficient at five level decay levels (d1, d2, d3, d4, d5). The most extreme and least detail coefficient of line current at level 4 and level 5 are utilized for the examination. The most extreme and least detail coefficient of line current at level 4 and level 5 are ascertained for all unique fault writes, for example, Single Phase to Ground, Double Phase Fault, Double Phase to Ground Fault and Three Phase Fault utilizing wavelet tool kit. The most extreme and least detail coefficient of ordinary condition (pre-fault) values at level 4 and level 5 are taken as reference and contrasted and unusual one's. In the event that the most extreme and least detail coefficient estimation of the signal surpassed that of an ordinary condition, a fault is recognized. The component acquired by handling the discrete wavelet change is given to ground system to fault arrangements purposes.

V. Daubechies Wavelet

These wavelets depends on In-grid Daubechies work, a group of orthogonal wavelets that defines a discrete wavelet transform and to be characterized by maximum number of disappearing moments for the given support. With each class of this type, a scaling function (called the father wavelet) generates an multi orthogonal resolution analysis. The Daubechies wavelets are supposed to have *A* number of highest disappearing moments, for the given support width *2*^ (A – 1).[2]

Daubechies wavelet have 2 schemes[5]

- D*N* using the length or number of taps
- DbA referring to the number of disappearing moments

Herein, D4 and db2 seems to be same wavelet transforms. From the available 2^{A-1} possible solutions of the algebraic equations, at a moment and orthogonality conditions, one with external phase scaling factor is chosen. Wavelet Transform can easily kept in practice by making use of fastest wavelet transform. Daubechies wavelets were broadly used in resolving a wide range of problems, that is self-similarity characteristic of a signal/fractal problems, signal discontinuities, etc. Also these wavelets were not defined in any terms of the resulting scaling functions as well as wavelet functions. So, they are impossible to write-down in closed form.

VI. Fault Classification Algorithm[6]

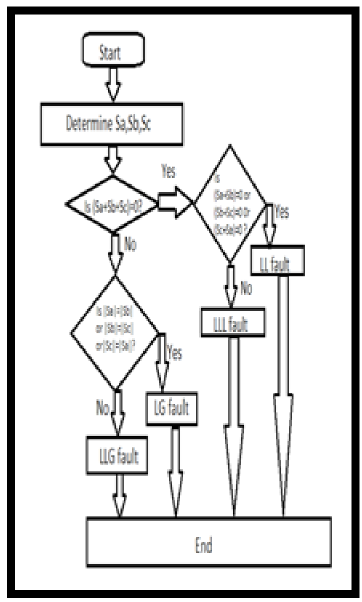

Fig. 15: Fault Classification Algorithm

Wavelet decomposition is done for the three phase faulted current waveform I_{abc} for all the three phases separately by choosing daubechies wavelet. Three level wavelet decomposition gives one approximation coefficient and three detailing coefficients for each phase. The sum of the approximation coefficients of all the three phases (Sa, Sb, Sc) is considered and given as input for fault classification code. Three level decomposition does not classify all the faults. So, the level of decomposition is increased to five. Now, the sum of the approximation coefficients of three phases when given as input to fault classification code can classify all the faults successfully.

Conclusion

In this paper, we observe that, from the PSCAD/EMTDC results of Fault analysis,

- The magnitude of fault currents decrease as the distance of fault location and fault resistance increases.
- The increase in the distance of fault location increases the resistance of the line and thereby the current flowing through the line decreases.
- Increase in the distance of fault location implies that the length of the conductor is increased. As we know that resistance is directly proportional to length.

- From Ohm's law, current is inversely proportional to resistance. The increase in the fault resistance decreases the fault current magnitude.
- LG fault is the most severe and most occurring fault. LG fault is severe at the source side. The increase in the distance of the fault location from the source makes the LLL fault most severe.
- Hence by using wavelet transform theory and applying five level wavelet decomposition to the current waveform, approximation coefficients are calculated and used in classifying the faults by writing the MATLAB code.

Future Scope

The Fault analysis can be performed by implementing transposition in the transmission line too. Approximation coefficients and detailing coefficients can be calculated by using different wavelets and different levels of wavelet decomposition. Fault classification can be performed by using Support Vector Machine, Multi resolution analysis, Artificial Neural Networks.

Thus this work could be extended for finding the fault location by using Distance relay protection scheme.

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Counter Measures to Mitigate Security Issues and Challenges in IOT

[1]Dr. K. Rajakumari, [2]Dr. M. Udhayamoorthi, [3]M. Jagadesh, [4]Dr. P. Hamsagayathri, [5]K.S. Mohan

[1]Department of CSE, Sri Shakthi Institute of Engineering and Technology, Coimbatore
[2]Department of IT, SNS College of Technology, Coimbatore
[3]Department of ECE, SNS College of Technology, Coimbatore
[4]Department of ECE, Bannari Amman Institute of Technology, Sathy, Erode
[5]Department of IT, SNS College of Technology, Coimbatore.
E-mail: udaya.manasu@gmail.com

ABSTRACT

Internet of Things (IoT) is an ecosystem of interrelated computing devices, mechanical and digital machines, objects, animals or people through the internet. The things in IoT is an object that assigned with an IP address and have the ability to collect and transfer the data over a network without manual intervention. IOT does not need any human to machine interaction, it seems to be one of the largest waves of revolution as per the research going on. As more and more IoT devices introduced and deployed in uncontrolled, complex environments, securing IoT systems presents a number of unique challenges. The quick development of IOT has derived with the challenges in terms of security of things. In this paper imperative study is done to reveal the security and privacy in internet of thing devices and also discussed the different counter measures to mitigate them which would give the future scope for next researches in Internet of thing drives.

Keywords: IoT, Security issues, DoS, spoofing, Man-in-the-Middle Attack, mitigation.

1. Introduction

The emerging trends in embedded technologies and the Internet have enabled objects surrounding us to be interconnected with each other. We envision a future where IoT devices will be invisibly embedded in the environment around us and would be generating an enormous amount of data. These data would have to be saved and processed to make it understandable and useful.

The Internet of Things (IoT) plays a extraordinary position in every portion of our everyday life. It includes fields such as healthcare, automobiles, entertainments, industrial appliances, sports, homes, etc. The frequency of

IoT relieves several daily actions, augment the method that cooperate with the adaptable surroundings, and supplement the social communications with other people and objects.The security levels in the production turn out to be doubtful with standards. Vulnerabilities aim the physical interfaces of IoT devices, wireless protocols, and user interfaces. It is imperative that intrusion analyst understand how to levy the attack facade, examine threats, and expand the potential to sense assault in IoT location.

2. IoT Architecture

The principle objective of IoT is to facilitate the devices to be associated using whichever network from anywhere. Henceforth IoT is decided to recognize appropriate policies about construction and interconnection of a variety of sensors and devices[1] and as a part of Mobile Adhoc Networks operations also.[13]

Layer 1 – Physical and Data Link Layer

These layers recognize the objects and sensors capture the data information. This layer includes knowledge correlated to sensors, embedded devices, and classification.

Layer 2 – Network Layer

This layer is to transport the composed statistics to the dealing out structure. To do this, itrelies on the communication networks like the Internet, mobile communication, and WirelessSensor Networks.

Layer	Security Threat
Application	Static Password, SNMP Private Community Strings
Presentation	Viruses, Worm
Session	Personal Information Retrieval, Root Privilege Access, Net Bios, DOS
Transport	Endpoint Identity
Network	Preventing unauthorised access to internal system
DATA	ARP spoof, MAC Flooding
Physical	Inadequate Power, Unfettered access, Open wall ports

Fig. 1: Security threats in IOT Model

Layer 3 – Transport Layer

This layer route the data, examine it and accumulate in a catalog which can be used later onrequirement. It contains large cloud processing systems and statistics storage systems.

Layer 4 – Application Layer

All the user specific applications or industrial applications are accessible in this layer.Applications like Smart Home and Smart Traffic are the great examples.

After talk about the IoT representation and its layer-wise functionalities, next section confers a variety of probable threats on the IoT strategy.

3. Threats on Each Layers

As huge quantity of data composed and processed by IOT is being used by normal users or industries. This gives a roadmap for many hackers.[2] susceptible data from IoT systems like position data, economic data, credit card data, etc. can be chop by the impending invaders. Besides, IoT elements like nodes, to molest the third party entities[3] can be compromised. Tobetter view security threats in IoT, it is briefly discussed several possible cyber-attacks on IoT applications as shown in Figure 1. On each layer invaders typically invade with different ways which are also an important era of discussion but it is beyond the scope of this paper so a brief overview is elaborated of such attacks on each layer below.

Device Tampering: Here, aggressors physically exchange the inventive sensor node by malicious node. This way it can harm the network by receiving total power of it.

Signal Jamming: Hindering the message canal in the midst of the nodes is the chief aspire of this attack.

Spoofing: A counterfeit message will be propel to the system craft it with assumption as it was coming from the unique node. It may escort the attacker toachieve full control of the system making it vulnerable.

Eaves dropping: Assuming wireless, RFID system lead to snooping sensitive information like passwords on the fly of data.

Sinkhole Attack: One way to dam the network and augment the energy expenditure of nodes. The sinkhole generates disagreement in the middle of malicious node and adjacent nodes to increase the message canal entrée. This guide to extra serious attacks like denial of service (Dos) attacks.

Man-in-the-Middle Attack (MITM): In this the attackers watch or manage the message between the two clients. Not only this it forge the identity and talk devoid of any doubts.

Data Tampering: For the individual reimbursement, one can tampers the information by digging up or amending the IoT objects data.

Denial of Service Attack (DoS): This aim the accessibility facial appearance and attempt to close the scheme to unavailable for others.

Sniffer: sensitive information is collected from the passage; invaders embed sniffer or logger codes to whip files, passwords and communication texts.

Session Hijacking: To utilize the imperfection in session organization, this discloses the user individuality. Enchanting identity of individuals, invaders doanything that it desire.

Distributed Denial of Service (DDoS) Attack: Similar to DoS attacks it can be completed by captivating manage of manifold fatalities and treat as attackers.

For a better understanding of the security requirements and solutions to IoT related problems, this section discusses various recent studies in IoT. Following table summarizes the above discussed recent works in various aspects.

Table 1: Summary of security issues IoT

Applications	*Algorithm*	*Realization*	*Confront*
Real-World confront in IoT[4]	Cryptographic algorithms	Improvement of security possibility defending devices protect tidy devices	Virtual Attacks recurrently modernize the firmware
Diminish the safety risks in IoT system[5]	business security policy	recognize rogue devices frustrate possible IP passage	undeveloped IoT devices watch and prevailing
Study of secluded Patient scrutinize System[6]	analyses security rations and later on estimate that are to be snooped	device-specific security algorithms identified	Quality Energy efficiency in IoT nodes
Safety connected finest carry out for the operation of IoT plan[7,15]	Shodan and Censys is anlysed in its place of web	authentic IoT devices in a gigantic network	Cyber-physical attacks
Safety risk and knowledge to conquer[8]	worm secure IoT structural design	layer based security challenges analyzed	verification DDoS attacks
Network intrusion detection (NID)[12]	Monitoring the devices for malicious activity	Equip the tools to IoT based network devices	Port scans insufficient to secure accurately

Contd…

Contd...

Applications	***Algorithm***	***Realization***	***Confront***
IoT in medical applications[11]	plan pedestal on smart treatment system	remote check of Health Care System	Data security
The smart cities projects in IoT scenario[10,13-14]	Semtech and SigFox's technology	arrange IoT campaign in a low cost	Networking Transportation policy concern
social lens secure the IOT[9]	Three case studies done in the IoT networks	incidental safety of IoT	Offshore growth of IoT plans

4. Counter Measures to Mitigate the Security Threats

Various vulnerabilitiesare revealed and with such challenges some of the prevention measures are contributed so that it gives an immense pleasure to next research in different security era whichis depicted in each issue.

Self-doubting Web Boundary

Deals with

- GUI built into IoT devices that collaborate amid the apparatus, parallel tolerate an intruder to raise illegal entrance to the device.

Vulnerability

- Financial credit details
- Scrawny defaulting certificate
- Cross-site Scripting (XSS)
- SQLInjection
- Assembly organization

Counter Measures

- Default credential must be distorted throughout preliminary company
- Ensure key resurgence mechanisms are strong and do not furnish an invader with data having a valid account
- Certify credentials should not be exposed
- Weak password not allowed
- Lock the account after failure attempts.

Unconfident Network Forces

Deals with

Vulnerabilities in the complex services admission the IoT device that might achieve illicit access to the appliance or allied figures.

Vulnerability

- Vulnerable forces
- Shield excess
- Untie port via UpnP
- Vulnerable UDP forces
- Denial-of-Service
- DoS via association
- Device Fuzzing

Counter Measures

- Compulsory ports are showing and existing
- Forces are not exposed to defense excess and fuzzing attack
- Guarantee not vulnerable to DoS attacks
- Make sure network ports are not bare to the internet via UpnP

Timid Cloud Edge

Deals with

Entail deprived validation reins or data travelling in an unencrypted arrange allow an enemy admittance to the applianceor the fundamental data.

Vulnerability

- Explanation details
- None description shut out
- Credentials bare in Network passage.

Counter Measures

- Evade passwords and ideally evasion usernames to be altered original setup
- Itemize password reset mechanisms
- Guarantee lockout mechanism following failed login attempts
- Apply two factor confirmation

Unconfident Mobile Edge

Deals with

Puny verification or unencrypted statistics means permit an attacker entrance to the device or essential data of an IoTmachine that exploit vulnerability

Vulnerability

- Credential not locked
- Network Traffic seen the open credential

Counter Measures

- Guarantee consumer financial records cannot be temize using functionality such as code word rearrange device
- Guarantee lockout mechanism after failed login attempts
- Make certain credentials are not depiction whilst associated to wireless networks
- Realize double factor authentication

Inadequate Security Configuration

Deal with

Enforces to exploit the physical powerful passwords. IoT device could be attacked allocate illegal entrance to the mechanism or the data.

Vulnerability

- Granular Permission deficient
- Code word safety Options lacking
- No Security Monitoring
- No Security Logging.

Counter Measures

- Divide usual users from managerial client
- Encrypt data at rest or in transport
- Strong secret word guidelines
- Facilitate event logs
- Audit the security

5. Conclusion

This paper explains the significance of IoT where it continues to cultivate at a rapid rate and root into each and every field of real life. It also implies the architecture, security threats that curtail the development of IoT applications and its counter measures. Privacy is crucial in IoT especially as the characteristics of such a network are different than the typical Internet network. Such issues and requirements are identified and discussed in this paper. Thereby different countermeasures to defeat the attacks related to security is discussed which would gain the scholars the opportunity for the future research.

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Project Management in GSD Environment

Dr. S. Ramacharan

Associate Professor, Information Technology Department, G. Narayanamma Institute of Technology and Sciences, Hyderabad
e-mail: s.ramacharan@gnits.ac.in, s.ramacharan@gmail.com

ABSTRACT

One of the most exceptionally important tasks in software development life cycle is to produce precise effort estimations and schedule. Effort estimate is used as input to project planning, budgeting, pricing policies and investment analyses by the developers. Missing or Incomplete data are exasperation to a certain extent everywhere but especially in effort estimation it is a greater hindrance. Over estimation of the software effort can result in losing the chance to win a bid and underestimation can lead to detrimental effect on the quality of software or monetary loss. Accuracy in effort estimation is decisive for developers and customers also it is required to do preplanning, budgeting, risk analysis and productivity assessment and customers requires estimation for taking place in contract negotiation process by the developers. Accuracy of data during effort estimation is termed as the characteristics of the dataset and it is a great deal of uncertainty in such datasets. Quality of data is the major challenge in Software estimation because missing values leads to High degree of inaccuracy and the missing value is commonly measured to ignore the whole project data or its feature. All the popular empirical estimation models require accurate inputs for estimation of effort or in other words, the accuracy of the output of these models is depends upon the accuracy in the input parameters. It is very difficult to obtain such accurate information at the early development stage of a software project. Controlling the huge uncertainty in existing estimation model is hard since it could not be modelled purely based on mathematics. These issues led to the introduction of variety of techniques to solve the relevant issues of effort estimation in GSD projects. The objective of this chapter is to identify what are the factors that will have major impact in GSD projects and how to overcome these factors while calculating effective estimation for a GSD projects.

Keywords: Effort Estimation, GSD (Global software development), socio-cultural distance, Geographical distance, Critical Success Factor (CSF).

1.1 Introduction

Global Software Development (GSD) has grow to be a one of the major business need internationally worldwide which is been previously cited to be off shore development, Software development over Internet, multi-site software development, distributed software project development.

Global Software Development assumes and follows sun rule i.e. exploit the Complete time for the software project development therefore GSD is also called no sun set in software development.[1] GSD has three distinct but complementary perspectives: Business perspective, Socio Economical perspective and Technical Perspective. The incident of Global Software Development (GSD) is taking possible and the implication of GSD boost with the course of time. GSD offers highly skilled personal with low cost. It is one of the reasons behind shifting software industry from co-located development to GSD. This shifting brought some new challenges in software development. The problems arising from the geographical, temporal and socio-cultural distance are the main challenges for GSD. Lack of formal communication generates misunderstandings in requirements or changes in the requirement specification. Real time contact between the distributed team is more difficult with temporal and geographical difference. Socio-cultural difference leads problems, such as, different opinions about the nature of the software development process.[9] Language problem also discourages employees to online meeting. To avoid this fear he/she prefers to asynchronous communication e.g. email etc. However, sometime one cannot express a problem through only words; he needs gesture. Body language and pitch. Moreover, the distance and complexity of coordination is directly proportional. As distance increases, the complexity of coordination increases in software development process. This complexity also arise lack of familiarity with remotely located colleagues and increase in communication cost as well. Apparently, trust and teamwork cannot take birth in this situation. GSD environment erg to reduce these complexities also needed to enhance the ability to focus on coordination of resources. It is important to overcome these challenges in development and also essential to offer generic solutions to these challenges.

1.1.1 GSD

The software development process is determined as a collection of actions, procedures, practices and technologies which is used by people and companies for software development and to maintain associated software and products. The main concern in the software development process is established on the following basis: – The quality of the software mainly dependent on the quality of the process used. It is possible to define, manage; measure, as well as software process can be improved. Even though if well defined software process is used it is not that much simple to develop software. The GSD is characterized based on how the development team geographically distributed on a worldwide scale which leads to computation of globalization of efforts required. Majority of GSD projects fails due to varying estimates which is available widely so software development filled with many difficulties.The record of descriptions that differentiate GSD from normal (centralized) development is small and specific: distance (the distance between developing team scattered from each other and these developers from their customers or end users); time-zone differences (time zone mainly a puzzling factor with distance); and national culture (it comprises language barrier, traditions, custom). These three parameters will have major effects on various levels:

- **Strategic issues**: The choice whether a software project should be developed by globally distributed teams, where this software project can be better developed, and how this software project to be divided across multiple sites is a toughest task. Many analyst expressed options about the risks and benefits of global project development. This GSD development depends upon resources availability at different sites, degree of expertise in technology, infrastructure required for development so on. Many appropriate models are essential under various circumstances.
- **Cultural issues**: In Global Software development there is a need for close collaboration between individuals with diversified cultural backgrounds. Culture differs in many dimensions from national, ethnic, professional so on. Many people find such differences which leads to severe and persistent misunderstanding. For example, e-mail in some culture may be offensive for someone with different background. Culture differences frequently intensify communication problems.
- **Knowledge management:** The advantages of GSD benefits cannot be explored if there is no valuable information and knowledge-sharing mechanisms among the people. Even substandard documentation can also leads to unsuccessful collaborative development. Generally documentation depends on confrontation among developers but in context of Global Software Development the effectiveness of documentation is vital for all aspects such as required to simplify unspoken inference and doubts, and to support maintainability.
- **Technical issues:** When various teams work on different sites then one of the crucial problems is lack of synchronization among them. So there should be uniform milestones between the members and clear entry point and exit point for every task. Naturally, risk management has not taken into account possible influence on the distribution, dissimilar cultures, schedule and outlook. The overheads for software projects are amazing related to control and coordination. Due to the differences in distance in GSD project neither people cannot synchronize by glance between compartment walls nor will managers have a control by visiting the team's office. In addition, time zone differences can be resolved related to issues or algorithm clarification on fly by

a quick phone call. Ever since networks traverse globally distributed places are frequently sluggish and untrustworthy. So the tasks that require broadcasting vital data must be thoroughly designed and executed for example in case of configuration management it is very essential and important. In case of GSD projects it is important to control product changes and also ensure all the concerns related to the project. Many tools and techniques have been developed in GSD environment to control and coordinate the development teams working. Majority of these tools focus on formal communication and non interactive communication channels. The conventional problems and existing challenges of GSD can be summarised as follows. Companies are searching for aggressive benefits in development in terms expenditure, quality and flexibility, gazing for increased productivity and reduced risk. Most organizations are forced to explore the competitive benefits for global solutions. There are two major choices at present employed: offshore outsourcing and offshore in sourcing.

1.1.2 Insufficient Communication

Initial stages of software development require a large amount of healthier communication. Software projects require two Communication needs such as a clear formal, official communications and well-understood interface. In critical tasks If the interface is designed badly there is a threat for time lose and also task descend through the cracks. Vital communication channel can be surprisingly disabled during development such that developers not situated jointly will have less informal, impulsive transformation across sites. Informal transformations helps people in knowing what is progressing around them, what other individuals are doing in the project, what represents different fragments of the project are in, who has knowledge and skills in which area, and several other necessary information that facilitate developers to work together efficiently. One of the issue produce for any software project is extended periods. The deficiency in ongoing conversation from multiple sites results in misalignment and rework. Basically if the project is unsure then communication channel plays a vital role and becomes more important. These affairs are even more composite in case of outsourcing arrangements. In many cases restricted or filtered communication is used due to the fear of losing intellectual property or other proprietary information concerned to product or schedules. This frequently damages this critical channel.

1.1.3 Issues Related to Project and Process Management

When teams accommodating processes will have deficiency in synchronization between sites will be critical for example, if the team at one location and the test group at another location if they define unit-tested code in a different way. Synchronization requires uniform milestones and a precise entry point and exit point criteria. Although concurrent development process models suggested in the literature and they are used, in Global Software Development it is very difficult for developing effective concurrent engineering philosophy due to unpredictable requirements, unbalanced specifications, and the lack of good tools which support collaboration across schedule and space, and deficiency in of informal communication. In few cases they practice risk management in a conventional fashion, not considering the probable encounters of diverse cultures and attitudes.

1.2 Project Management in GSD

Because of time zone, geographic and communication differences, the project management is now a great challenge in GSD. Project management seems to be same entity for both co-located and GSD environment and, an experienced project manager can set the project on the success path.[1] Some concealed risks sway project's success. Project managers are advancing and updating themselves according to the new paradigm of GSD. Both (literature and industry) are lacking to provide the standardized approaches. Sights of GSD process management and problem solution. Some generic problems and hurdles need to solve and remove. According to conclusion about global project management, it is recommended to overcome problems of communication maimer. Employees also hesitate to adopt new means of interactive communications. Switching the personnel between their partners according to task distribution causing problems associated with wrong approach in project process distribution that affects the overall result of the project. There are also some problems of unclear-shared goals in the GSD environment. A project manager has to share this knowledge with the employees and the organizations. Effort estimation[3] is one of important activity of project management. It is closely associated with risk management.[4] For GSD project, risk management requires more intension because there are some additional GSD factors involved. GSD factors, e-g multi sourcing, geographical distribution, temporal diversity, socio-cultural diversity, linguistic diversity, contextual diversity and political and legislative diversity are the main roots for GSD threats that imperial the success of global project. These threats are directly affect the GSD project management activities.[9] These threats reveal the weird nature of GSD project. They also generate a force that develops obstacles in a project.

Project managers require significant effort[5] to forecast obvious and hidden risks associated with GSD factors, and perform necessary precautions to overcome challenges associated with these factors to succeed in GSD.[7] All these GSD factors affect project management activities and thus should be taken into account by project managers when estimating project schedule. Major Challenges in Global Software Development arise from geographical, temporal and cultural distances.[8]

The major consequent challenges are

i. Loss of Tameness
ii. Coordination and Control
iii. Loss of Communication Richness

1.3 Need for Coordination in GSD

(i) To manage interdependencies and achieve project goals when several actors are involved and multiple activities are performed

(ii) To suggest compatible process across sites to reduce distances and the amount of coordination required between client and vendor.

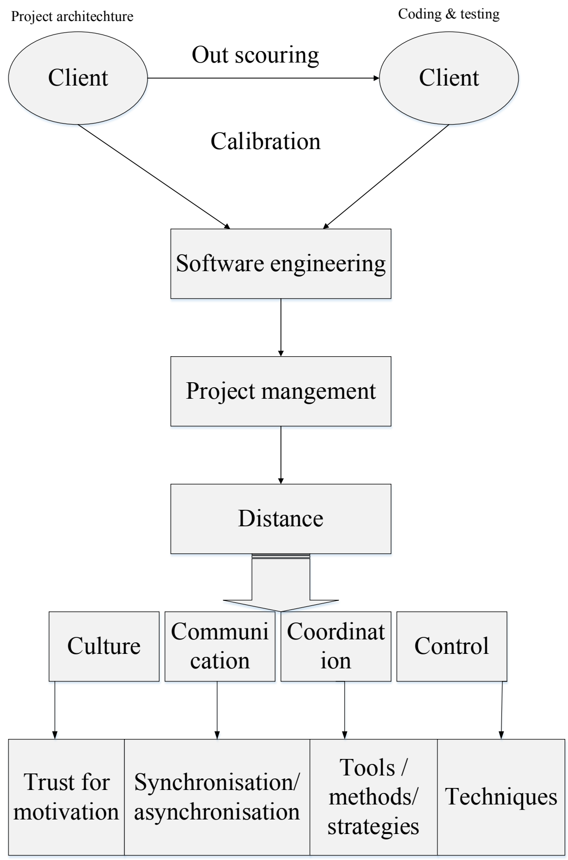

Fig. 1.1: Coordination between Distributed Teams in GSD Environment

GSD Issues

- Geographical Distance
- Temporal Distance
- Socio-cultural Distance
- Organizational Distance
- Technological Distance
- Knowledge Distance

1.3.1 Research Methodology

Interviews were chosen as the major research methodology. Depending on the communication between the partners, interviews can be divided into telephone interviews and personal interviews with both persons facing each other Telephone interviews have several advantages over personal interviews, mainly due to the ease of access: ever since the interviewer does not have to travel to the interviewee, the costs of telephone interviews are much lower. In addition, a large number of interviews can be conducted within a short amount of time. It is also easier to access interviewees who are reluctant to sacrifice time for a personal meeting. On the other hand, there are many disadvantages of telephone interviews compared to personal ones: Since only spoken words are transmitted over the telephone, it is harder to get information. This reduces both the possibility of the interviewer to formulate complex questions and his or her ability to obtain all of the interviewees' responses (e.g., their mimic action). The respondent might also not be willing to discuss sensitive topics over the telephone. Besides, the interviewer has less control compared to a personal interview. The interviewee can, for example, easily terminate the interview by simply hanging up the phone. Thus, it is recommended to use the telephone interview as an alternative only in certain circumstances. We tried to follow this guideline by conducting as many interviews as possible in person and only used telephone interviews if there was no other option. We also tried to minimize the problem by mailing the questionnaire to the interviewees in advance so that they had all questions in front of them. This helped very much to avoid misunderstandings during the interviews. Throughout the interview, we used a detailed questionnaire that contained both open and closed questions. All answers were recorded[9] and, with the exception of one, transcribed literally. The interview transcription and the notes were then analyzed using coding: Pieces of the answers were categorized and grouped together in order to identify commonalities and differences.

All interviewees confirmed that the six goals presented.

- Costs
- Time
- Quality
- Staffing
- Intellectual property protection
- Proximity to customer

Based on the outcomes of the interview study, several changes were applied to build a model which demonstrates the impact of GSD.

1.3.2 Problems in Communication, Coordination, and Control

The factors identified in the literature study as having an impact on communication problems were physical distance, language differences, cultural differences, differences in company culture, and common experiences of working together. Infrastructure distance, time shift and process maturity.[3] Out of these factors, time shift was mentioned most often as having the biggest impact on communication problems. Time shift between sites caused many problems because of delayed communication. The results are grounded in both a systematic literature review and a subsequent interview study; there is a set of threats to validity that have to be considered when interpreting the data.

- It was not possible to keep the factor deficiency of belief within the model because it was understood differently by the practitioners.
- Interviews were given to an outsider. This might have prevented the practitioners from reporting all problems openly.

The impact of all of the factors identified here does not only depend on whether a project is globally distributed or not, but also on the question of what the distribution of work across sites looks like: For example, the impact of task coupling and cultural differences on productivity is higher in a scenario in which closely coupled tasks are assigned to sites with large cultural differences compared to a scenario in which only tasks with loose coupling are assigned to different sites that have only low cultural differences between them.[4]

However, we discovered that in practice, work assignment is done rather unsystematically and takes into account only few factors, such as the availability of the workforce and local cost rates. This discrepancy between decision criteria and the fact that, at the same time, the practitioners reported many problems caused by the factors identified here indicates a potential for improvement.

We thus see a need for systematic decision support in GSD task allocation that can help practitioners to efficiently take into account all relevant influencing factors for their allocation decision and thus decrease the risks of global software development. In doing so, models like the one developed here are needed for understanding the impact of allocation decision on project success.

(A) Solutions to GSD Difficulties

Though many probable solutions are exists for every problems identified, but the organizations mainly focused on work standardization, planned assets, committed process and risk management for the solution. Evaristo suggested a solution that comprises integration and enhancement of trust between global teams. Carmel has supported effective requirements engineering and formal development process which focus on initial planning is mandatory for distributed project, assessing the project characteristics and the unit of work available for the project. furthermore, the process commitment plays an vital role to begin the communication between global teams. An additional solution applied was guiding in soft skills which projects mainly on nontechnical factors such as authority, communication, traditions, context involvement, project administration, and scientific training. When the global teams do not use the same process then standardization is appealed by considering three strategies such as driving standardization, merging practical components from different sites into novel methodology, and enforcing high-level guidelines. Risk management is drastically growing in both organizations. Some companies follow traditional risk management without taking the possible impacts of distribution, dissimilar cultures, schedule and attitudes. This has led to the necessity for global risk management process. Organizations are spending on the real requirements discovery which is essential for project characteristics and travel limitations. In every project major effort spend for the endorsement of project artifacts. At last, assimilation activities are conducted focusing mainly at trust achievement. Majority of these activities are achieved when teams meet & few of them are developed virtually.

(B) Global Software Development Critical Success Factors (CSF)

Based on organizational procedures Critical Success Factors are directly identified. For the similar activity it is possible to achieve different CSF related to the policies acquired by every organization. Summarizing the outcomes following critical success factors was identified. Formal software development process is considered to be significant factor for global projects. Variant CSF comprises huge allocation in training that evolved in enhanced relationships. The preliminary planning was vital for assessing global projects accurately and to choose the appropriate unit to allocate every project. Process commitment was measured as a success factor since it was the primary contact among global project teams. Combining activities enhanced soft skills of persons, improved beliefs and reducing the cultural differences among people. Finally, integration has enhanced the interaction and feedback.

1.4 Results

Even though the results are grounded in both a systematic literature review and *a* subsequent interview study, there is a set of threats to validity that have to be considered when interpreting the data.

- It was not possible to keep the factor "lack of trust" within the model because it was understood differently by the practitioners.
- Interviews were given to an outsider. This might have prevented the practitioners from reporting all problems openly.

The impact of all of the factors identified here does not only depend on whether a project is globally distributed or not, but also on the question of what the distribution of work across sites looks like: For example, the impact of task coupling and cultural differences on productivity is higher in a scenario in which closely coupled tasks are assigned to sites with large cultural differences compared to a scenario in which only tasks with loose coupling are assigned to different sites that have only low cultural differences between them.

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Web Mining

[1]N. Vani, [2]Dr. T.M. Veeragangadhara Swamy

[1]Assistant Professor, Department of Computer Science and Engineering, Rao Bahadur Y. Mahabaleswarappa Engineering College, Bellary-583104

[2]Professor, Department of Computer Science and Engineering, Rao Bahadur Y. Mahabaleswarappa Engineering College, Bellary-583104

e-mail:vanimtech.z@gmail.com, Swamytm@gmail.com

I. Introduction

Today internet is faster changing technology with rapid growth and increasing demands of users day by day. To extract information from huge documents of web as per user requirements at a faster rate is most challenging task. Web mining is useful to get data in faster rate as per user specific interest. it reduces time of server and cost saving and increases speed of response and improves performance of server system. Web mining gets information which is useful and finds knowledge from user click streams, hyperlinks and behavior of user. There are 3 categories in web mining such as web structure mining, web content mining and web usage mining. The web structure mining gets structure of data been accessed by user. The web content mining gets information about type of content being extracted by user. The web usage mining records every click made by user and identifies patterns from log files. The main objective of web usage mining is used to identify user interest and predicts user navigation

Web Mining is the extraction of interesting and potentially useful patterns and implicit information from artifacts or activity related to the World Wide Web. Web usage mining provides the support for the web site design, providing personalization server and other business making decision, etc. In order to better serve for the users, web mining applies the data mining, the artificial intelligence and the chart technology and so on to the web data and traces users' visiting characteristics, and then extracts the users' using pattern. It has quickly become one of the most important areas in Computer and Information Sciences because of its direct applications in e-commerce, CRM, Web analytics, information retrieval and filtering, and Web information systems.

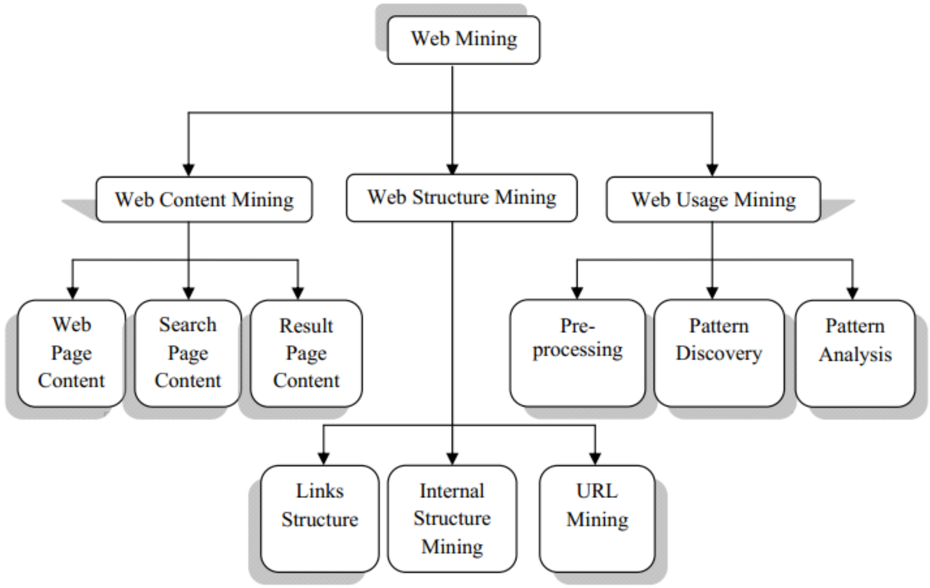

Fig. 1: Web mining taxonomy

There are three types of web mining:

1. Web content mining
2. Web structure mining
3. Web usage mining

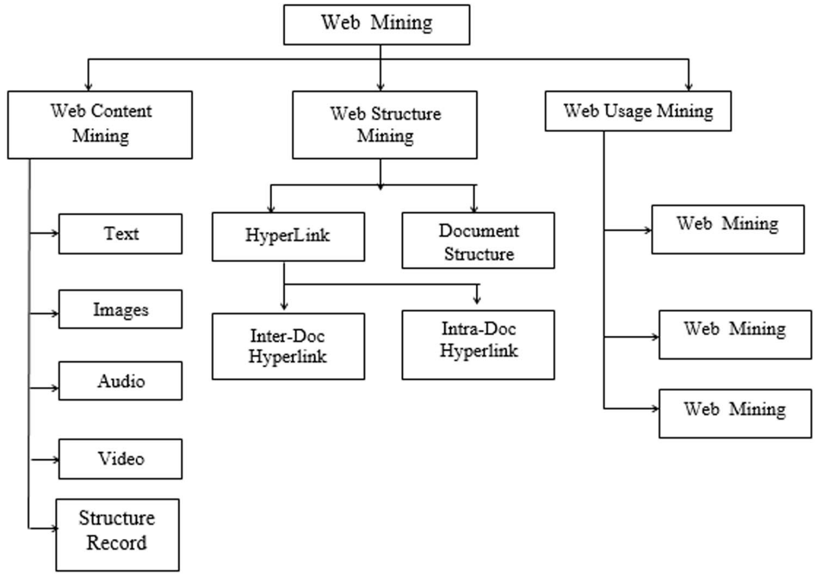

Fig. 2: Web mining types

1. Web Content Mining

Web content mining is the process of extracting useful information from the contents of web documents. Content data is the collection of facts a web page is designed to contain. It may consist of text, images, audio, video, or structured records such as lists and tables.

Application of text mining to web content has been the most widely researched are following:

- **Topic Discovery And Tracking,**
- **Extracting Association Patterns,**
- **Clustering of Web Documents**
- **Classification of Web Pages.**

Research activities on this topic have drawn heavily on techniques developed in other disciplines such as

- **Information Retrieval (IR) and**
- **Natural Language Processing (NLP).**

2. Web Structure Mining

The structure of a typical web graph consists of web pages as nodes, and hyperlinks as edges connecting related pages. Web structure mining is the process of discovering structure information from the web. This can be further divided into two kinds based on the kind of structure information used.

- **Hyperlinks:** A hyperlink is a structural unit that connects a location in a web page to a different location, either within the same web page or on a different web page.
  - **Intra-document hyperlink:** A hyperlink that connects to a different part of the same page is called an intra-document hyperlink.
  - **Inter-document hyperlink:** A hyperlink that connects two different pages is called an inter-document hyperlink.
- **Document Structure:** The content within a Web page can also be organized in a tree structured format, based on the various HTML and XML tags within the page.

3. Web Usage Mining

Web usage mining is the application of data mining techniques to discover interesting usage patterns from web usage data, in order to understand and better serve the needs of web-based applications. Usage data captures the identity or origin of web users along with their browsing behavior at a web site. web usage mining itself can be classified further depending on the kind of usage data considered:

- **Web Server Data:** User logs are collected by the web server and typically include IP address, page reference and access time.
- **Application Server Data:** Commercial application servers such as
  - **Weblogic**
  - **StoryServer**

  The significant features are to enable E-commerce applications such as B2B E-commerce and B2C E-commerce. A key feature is the ability to track various kinds of business events and log them in application server logs.
- **Application Level Data:** New kinds of events can be defined in an application, and logging can be turned on for them for generating histories of these events.

II. Real Time Applications

The web applications being developed at a much faster rate in the industry than research in web related technologies. Many of these are based on the use of web mining concepts, even though the organizations that developed these applications, and invented the corresponding technologies.

1. Web Search—Google

Google is one of the most popular and widely used search engines. It provides users access to information from over 2 billion web pages that it has indexed on its server. The quality and quickness of the search facility makes it the most successful search engine. Earlier search engines concentrated on web content alone to return the relevant pages to a query.

Google was the first to introduce the importance of the link structure in mining information from the web. PageRank, which measures the importance of a page, is the underlying technology in all Google search products, and uses structural information of the web graph to return high quality results. The Google toolbar is another service provided by Google that seeks to make search easier and informative by providing additional features such as highlighting the query words on the returned web pages. The full version of the toolbar, if installed, also sends the click-stream information of the user to Google. The usage statistics thus obtained are used by Google to enhance the quality of its results. Google also provides advanced search capabilities to search images and find pages that have been updated within a specific date range. Built on top of Netscape's Open Directory project, Google's web directory provides a fast and easy way to search within a certain topic or related topics. The advertising program introduced by Google targets users by providing advertisements that are relevant to a search query. This does not bother users with irrelevant ads and has increased the clicks for the advertising companies.

2. Web-Wide Tracking—DoubleClick

Web-wide tracking is tracking an individual across all sites he visits, is an intriguing and controversial technology. It can provide an understanding of an individual's lifestyle and habits to a level that is unprecedented, which is clearly of tremendous interest to marketers. A successful example of this is DoubleClick Inc.'s DART ad management technology.

DoubleClick serves advertisements, which can be targeted on demographic or behavioral attributes, to the end-user on behalf of the client, i.e. the web site using DoubleClick's service. Sites that use DoubleClick's service are part of The DoubleClick Network and the browsing behavior of a user can be tracked across all sites in the network, using a cookie. This makes DoubleClick's ad targeting to be based on very sophisticated criteria.

3. Understanding Web Communities—AOL

One of the biggest successes of America Online (AOL) has been its sizeable and loyal customer base. AOL provides them with useful information and services. Over time these communities have grown to be well-visited waterholes for AOL users with shared interests. Applying web mining to the data collected from community interactions provides AOL with a very good understanding of its communities, which it has used for targeted marketing through advertisements and e-mail solicitation. In return, consumer survey and new product development experts of the sponsoring organization get to participate in the community, perhaps without the knowledge of other participants. The idea is to treat the community as a highly specialized focus group, understand its needs and opinions on new and existing products, and also test strategies for influencing opinions.

4. Understanding Auction Behavior—eBay

eBay started as an online auction house in the 90s for people to sell collectibles and used goods to one another. Today, 80% of items sold on the platform are new, and 89% of items are sold at a fixed price.

eBay is taking steps to make its platform look and operate more like Amazon. It's encouraging sellers to offer free guaranteed 3-day shipping. It's combining product listings from sellers with the same item, enabling consumers to find the best price more easily. It also launched a Best Price Guarantee, offering customers a 110% rebate on the difference between an item they bought on eBay and an identical listing on a competitors' website. eBay is operating more and more like a business-to-consumer retailer instead of a marketplace for other businesses.

The moves are starting to pay off. GMV growth (on a currency-neutral basis) started accelerating in 2018, growing 7% in the first half of the year. Still, that growth is considerably slower than other companies on this list, and slower than the overall growth of the e-commerce industry.

While eBay turns around its GMV growth, it's also working to increase its profit margin. It moved to intermediate payments itself by starting to cut ties with former subsidiary **PayPal**. The company will handle all of its payments in-house by 2021, which the company expects to provide significant value to sellers on the platform. That could result in both higher profits and better GMV growth.

In September 1995 eBay opened the first Internet based consumer to consumer auction. The corporate model was to provide a central market for the sale of goods. Independent sellers use eBay to sell their goods through auctions lasting from three to ten days so that bidders can bid at a convenient time. eBay's revenues are primarily from the posting and sales of goods. They extract two primary fees, a listing fee and a sales fee. These fees are increasing in the reservation price the auctioneer sets and the final sales price, with a maximum of 5 percent of the final sales price and listing fees under two dollars. The mean listing fee was one dollar for the monitors in our data set, and final sale fee was $2.50, with a median final sales fee of $1.50. For all of eBay at the time our data was collected the average fee per item auctioned–not all of which sell–was $1.41, and 7 cents in fees were generated for every dollar of sales.

5. Personalized Customer Experience in B2C E-commerce—Amazon.com

Amazon.com crafted a new business model in the 1990s for Internet entrepreneurs using the Web as a place for transactions. As consumers learned to replace physical distance with mouse clicks, Amazon created e-business and e-commerce models that generated massive profits for the online clearinghouse.

Amazon helps a seller create her own page on which she can list her products, that's serving consumers, too, although not directly. However, Amazon also offers its own products, both new and used, which consumers can purchase directly from Amazon. Now that Amazon has entered the digital media realm with its exclusive Kindle e-reader and selection of e-books, Amazon serves consumers in this way, too. Through the Amazon Prime service, Amazon provides consumers with discounted instant video and e-books as well as free shipping specials for a monthly fee.

The main effort is in getting a customer to the store. Once a customer is in the store they are likely to make a purchase — since the cost of going to another store is high — and thus the marketing budget is in general much higher than the in store customer experience budget (which keeps the customer in the store). In the case of an on-line store, getting in or out requires exactly one click, and thus the main focus must be on customer experience in the store.

When Amazon helps a seller create her own page on which she can list her products, that's serving consumers, too, although not directly. However, Amazon also offers its own products, both new and used, which consumers can purchase directly from Amazon. Now that Amazon has entered the digital media realm with its exclusive Kindle e-reader and selection of e-books, Amazon serves consumers in this way, too. Through the Amazon Prime service, Amazon provides consumers with discounted instant video and e-books as well as free shipping specials for a monthly fee.

6. Personalized Portal for the Web—MyYahoo

Yahoo was the first to introduce the concept of a "personalized portal," i.e. a web site designed to have the look-and-feel and content personalized to the needs of an individual end-user. This has been an extremely popular concept and has led to the creation of other personalized portals such as Yodlee for private information like bank and brokerage accounts. Mining MyYahoo usage logs provides Yahoo valuable insight into an individual's web usage habits, enabling Yahoo to provide personalized content, which in turn has led to the tremendous popularity of the Yahoo web site.

7. CiteSeer—Digital Library and Autonomous Citation Indexing

CiteSeer works by crawling the web and downloading research related papers. Information about citations and the related context is stored for each of these documents. The entire text and information about the document is stored in different formats. Information about documents that are similar at a sentence level (percentage of sentences that match between the documents), at a text level or related due to cocitation is also given. Citation statistics for documents are computed that enable the user to look at the most cited or popular documents in the related field. They also a maintain a directory for computer science related papers, to make search based on categories easier. These documents are ordered by the number of citations.

8. Google Analytics

Google Analytics is a web analytics service offered by Google that tracks and reports website traffic, currently as a platform inside the Google Marketing Platform brand. Google launched the service in November 2005 after acquiring developer Urchin.

Fig. 3: Google Analytics

Google Analytics is the most widely used web analytics service on the web. Google analytics is used to track the website activity of the users such as session duration, pages per session, bounce rate etc. along with the information on the source of the traffic. It can be integrated with Google Ads, with which users can review online campaigns by tracking landing page quality and conversions (goals). Goals might include sales, lead generation, viewing a specific page, or downloading a particular file. Google Analytics› approach is to show high-level, dashboard-type data for the casual user, and more in-depth data further into the report set. Google Analytics analysis can identify poorly performing pages with techniques such as funnel visualization, where visitors came from (referrers), how long they stayed on the website and their geographical position. It also provides more advanced features, including custom visitor segmentation. Google Analytics e-commerce reporting can track sales activity and performance. The e-commerce reports shows a site›s transactions, revenue, and many other commerce-related metrics

III. Conclusion

Web mining is an application of data mining and very useful extraction of useful information from web sites and server log file. There are 3 types of web mining such as web content mining, web structure mining and web usage mining. This chapter describes about basics of web mining and real time applications such as B2C E-commerce Amazon.com,Auction Behavior eBay,CiteSeer-Digital Library and Autonomous Citation Indexing, personalizing web- yahoo, Web Communities—AOL,Web Search—Google.

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Numerical Modeling

[1]Dr. G. Arul Freeda Vinodhini

[1]AP(SG), Department of Science and Humanities (Mathematics), Saveetha School of Engineering, Chennai, Tamilnadu

ABSTRACT

Modeling is essentially the basis of engineering. A model is a proper simplification of realism. Before the conduct of an experiment it is possible to predict the output by deriving analytical solution to the problem. This reduces the cost spent on the experiment and the time. But due to complexity instead of analytical solution, the numerical solutions are used. Numerical solution replaces a continuous problem by discrete where the solution can be obtained only at a finite number of points in space. In this chapter we discuss the numerical solution of models by FDM, FEM and DEM.

Keywords: Numerical Modeling – FDM – FEM - DEM.

1. Introduction

Modeling is the process of representing complex reality as mathematical equations. It's a tool used to design and analyze engineering problems. In engineering, modeling can be divided into two parts:

i. Physical/Empirical modeling: Engineers collect useful information by developing a empirical or semi-empirical algorithms for substantial application. Eg: Laboratory and in situ model tests.

ii. Theoretical/Analytical modeling: The development of a mathematical model with suitable assumptions for a corresponding physical problem is called theoretical modeling. This model results in a differential equation or algebraic equations. Most of the mathematical model of an engineering problem cannot be solved analytically and requires a numerical solution. With the advancement in technology, many numerical modeling software are available to solve engineering problems.

Numerical modeling has been broadly used in industries for both forward problems like simulation of space shuttle flight, material strength, ground water flow, earthquakes, medication formulae studies and in inverse problems like tomography, non-destructive evaluation (NDE), source location, structure deformation during loading tests, image processing. Although numerical models provide solutions to engineering problems, these results should be carefully analyzed with existing laboratory test data.

2. Chapter Contents

We consider the numerical solution of mathematical problems which are described by ordinary differential equations (ODEs) and partial differential equations (PDEs). The three classical choices for the numerical solution of PDEs are

1. The Finite Difference Method (FDM)
2. The Finite Element Method (FEM)
3. The Discrete Element Method (DEM)

The FDM is the oldest technique and is based upon the Taylor expansion to approximate the ordinary and partial differential equations. The FDM uses a topologically square network of lines for obtaining discretized PDE. This is the main obstruction of the method while handling complex problems in multiple dimensional spaces. This motivates the use of an integral form of the PDEs and subsequently led to the development of the finite element technique. The chapter is structured as follows. We start with the FDM for ODE, classified partial differential equations as elliptic, parabolic, hyperbolic and then FDM for PDE. FEM and DEM are discussed with comparison between the three techniques.

2.1 FDM for Solution of Second Order Ordinary Differential Equation

Taylor's series expansion of y(x) is $y(x+h)=y(x)+h\frac{y'(x)}{1!}+h^2\frac{y''(x)}{2!}+\ldots$

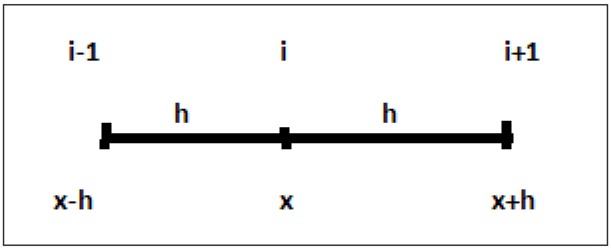
$$\mathrm{y}(\mathrm{x}+\mathrm{h})-\mathrm{y}(\mathrm{x})=\mathrm{h}\frac{y'(x)}{1!}+O(h)$$

$$y'(x)=\frac{\mathrm{y}(\mathrm{x}+\mathrm{h})-\mathrm{y}(\mathrm{x})}{h} \quad \text{(forward difference)}$$

Replacing h by –h,

$$y'(x)=\frac{\mathrm{y}(\mathrm{x})-\mathrm{y}(\mathrm{x}-\mathrm{h})}{h}. \quad \text{(backward difference)}$$

Thus the forward difference and backward difference formula for first derivativis $y_i' = \frac{y_{i+1} - y_i}{h}$ and $y_i' = \frac{y_i - y_{i-1}}{h}$ respectively.



Adding the above two relations we get,

$$2y_i' = \frac{y_{i+1} - y_i}{h} + \frac{y_i - y_{i-1}}{h}$$

$$2y_i' = \frac{y_{i+1} - y_{i-1}}{h}$$

Thus the Central difference approximation for y' is $\boxed{y_i' = \frac{y_{i+1} - y_{i-1}}{2h}}$

Consider $y_i'' = \frac{y_{i+1}' - y_i'}{h}$ (forward difference)

$$y_i'' = \frac{\frac{y_{i+1} - y_i}{h} - \frac{y_i - y_{i-1}}{h}}{h} \quad \text{(backward difference)}$$

$$y_i'' = \frac{y_{i+1} - 2y_i + y_{i-1}}{h^2}$$

Thus the central difference approximation for y'' is $\boxed{y_i'' = \frac{y_{i+1} - 2y_i + y_{i-1}}{h^2}}$

2.2 Finite Difference Approximation to Partial Derivatives

2.2.1 Classification of Partial Differential Equations

Let u be a function of two independent variables x and y. Consider the PDE of u of the form, $\left(A\frac{\partial^2 u}{\partial x^2} + B\frac{\partial^2 u}{\partial x \partial y} + C\frac{\partial^2 u}{\partial y^2}\right) + F\left(x, y, u, \frac{\partial u}{\partial x}, \frac{\partial u}{\partial y}\right) = 0$ where A, B, C are functions of x and y or constants.

If $F\left(x, y, u, \frac{\partial u}{\partial x}, \frac{\partial u}{\partial y}\right)$ is non linear then above equation is called quasi linear equation otherwise it is called second order linear equation.

The above equation is called Elliptic if $B^2 - 4AC < 0$

Parabolic if $B^2 - 4AC = 0$

Hyperbolic if $B^2 - 4AC > 0$.

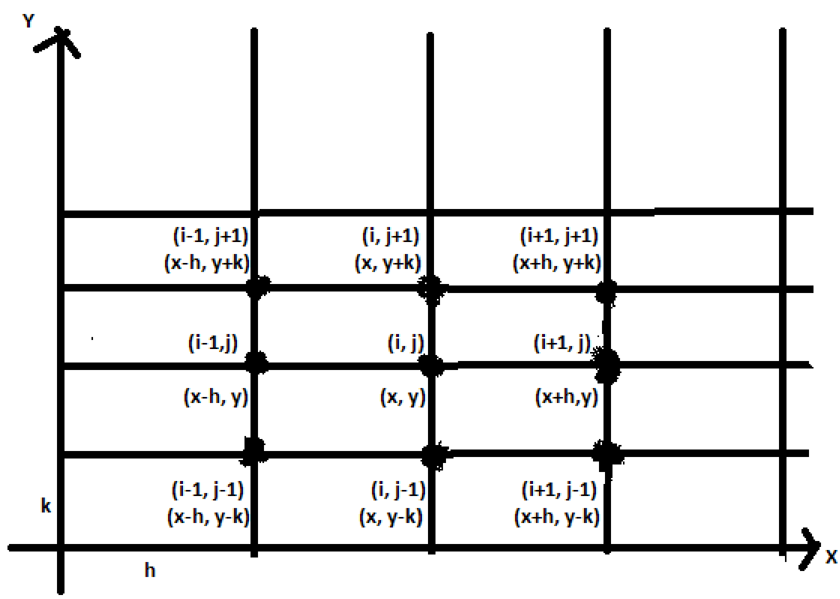
Example: Consider the equation $(x+1)U_{xx} - 2(x+2)U_{xy} + (x+3)U_{yy} = 0$.

It is hyperbolic when $y < -1$ or $y > 1$ and x ↑ 0 ; Elliptic for $-1 < y < 1$ and x ↑ 0; Parabolic when $x = 0$ or $y = \pm 1$.

2.2.2 Finite Difference Approximation

Consider a rectangular region in the xy plane with sides parallel to the axes. Divide this region into network of rectangles of sides h and k units by drawing lines $x = ih$, $y = jk$

$i, j = 0, 1, 2, 3...$ The points of intersection of these family of lines are called mesh points (or) lattice points (or) grid points. Thus, $U(x, y) = U(ih, jk) = U_{i,j}$.



2.2.3 Finite Difference Formula for Partial Derivatives

Consider $u(x, y_0)$, where x is a variable and y_0 is fixed then $u(x, y_0)$ is a single variable function.

Thus the Taylor's series expansion is

$$u(x_0 + h, y_0) = u(x_0, y_0) + h\frac{u_x(x_0, y_0)}{1!} + h^2\frac{u_{xx}(x_0, y_0)}{2!} + \ldots$$

$$u(x_0 + h, y_0) - u(x_0, y_0) = h\frac{u_x(x_0, y_0)}{1!} + O(h)$$

$$\boldsymbol{u_x(x_0,y_0)=\frac{u(x_0+h,y_0)-u(x_0,y_0)}{h}}\quad \textbf{(forward difference)}$$

Replacing h by –h

$$\boldsymbol{u_x(x_0,y_0)=\frac{u(x_0,y_0)-u(x_0-h,y_0)}{h}}\quad \textbf{(backward difference)}$$

Adding above two we get

$$2u_x(x_0,y_0)=\frac{u(x_0+h,y_0)-u(x_0,y_0)}{h}+\frac{u(x_0,y_0)-u(x_0-h,y_0)}{h}$$

$$\boldsymbol{u_x(x_0,y_0)=\frac{u(x_0+h,y_0)-u(x_0-h,y_0)}{2h}}\quad \textbf{(central difference)}$$

Consider $u_{xx}(x_0,y_0)=\dfrac{u_x(x_0+h,y_0)-u_x(x_0,y_0)}{h}$ (using forward difference)

$$u_{xx}(x_0,y_0)=\frac{\left[\dfrac{u(x_0,+hy_0)-u(x_0,y_0)}{h}\right]-\left[\dfrac{u(x_0,y_0)-u(x_0-h,y_0)}{h}\right]}{h}$$

(using backward difference)

$$\boldsymbol{u_{xx}(x_0,y_0)=\frac{u(x_0,+hy_0)-2u(x_0,y_0)+u(x_0-h,y_0)}{h^2}}\quad \textbf{(central difference)}$$

Similarly by fixing x constant (i.e) repeating the above procedure for the function $u(x_0,y)$ we get the difference formula w.r.to y.

All above formulae are given with grid notations as,

$$\frac{\partial u}{\partial x}=U_x=\frac{u_{(i+1,j)}-u_{i,j}}{h}\quad \text{(Forward)}$$

$$\frac{\partial u}{\partial x}=U_x=\frac{u_{(i,j)}-u_{i-1,j}}{h}\quad \text{(Backward)}$$

$$\frac{\partial u}{\partial x}=U_x=\frac{u_{(i+1,j)}-u_{i-1,j}}{2h}\quad \text{(Central)}$$

$$\frac{\partial u}{\partial y}=U_y=\frac{u_{(i,j+1)}-u_{i,j}}{k}\quad \text{(Forward)}$$

$$\frac{\partial u}{\partial y}=U_y=\frac{u_{(i,j)}-u_{i,j-1}}{k}\quad \text{(Backward)}$$

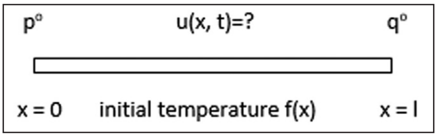
$$\frac{\partial u}{\partial y}=U_y=\frac{u_{(i,j+1)}-u_{i,j-1}}{2k}\quad \text{(Central)}$$

$$\frac{\partial^2 u}{\partial x^2}=u_{xx}=\frac{u_{i+1,j}-2u_{i,j}+u_{i-1,j}}{h^2}$$

$$\frac{\partial^2 u}{\partial y^2} = u_{yy} = \frac{u_{i,j+1} - 2u_{i,j} + u_{i,j-1}}{k^2}$$

2.2.4 Solution of 1- D Heat Equation (Parabolic Type)

Consider a rod of length l, let the ends of the rod be subjected to certain temperature say p and q, respectively. Let f(x) be the initial temperature given to the rod.



Our aim is to find the temperature of the rod at any point x and any time t (i. e) u(x, t). Based on physical condition, the 1D heat equation is given by $\frac{\partial^2 u}{\partial x^2} = a\frac{\partial u}{\partial t}$.

This equation contains 2nd derivative w. r. to x and 1st derivative w.r.to t. Hence 2 boundary condition and 1 initial condition is required to solve the above equation. Hence BVP of 1D heat equation is $\frac{\partial^2 u}{\partial x^2} = a\frac{\partial u}{\partial t} \quad 0 < x < l; \quad 0 < t < T$ with

BC: u(0, t) = p; u(l,t) = q for every 0<t<T

IC: u(x, 0) = f(x) for every 0<x<l.

Method 1: Bender – Schmidt scheme (or) Explicit Method

Here we use forward difference approximation for u_t and central difference approximation for u_{xx}. Hence above equation becomes

$$\frac{u_{i+1,j} - 2u_{i,j} + u_{i-1,j}}{h^2} = a\left[\frac{u_{(i,j+1)} - u_{i,j}}{k}\right]$$

$$u_{i+1,j} - 2u_{i,j} + u_{i-1,j} = \frac{ah^2}{k}\left[u_{(i,j+1)} - u_{i,j}\right]$$

$$u_{i+1,j} - 2u_{i,j} + u_{i-1,j} = \frac{1}{\lambda}\left[u_{(i,j+1)} - u_{i,j}\right]$$

$$u_{(i,j+1)} - u_{i,j} = \lambda\left[u_{i+1,j} - 2u_{i,j} + u_{i-1,j}\right]$$

$$u_{(i,j+1)} = u_{i,j} + \lambda u_{i+1,j} - 2\lambda u_{i,j} + \lambda u_{i-1,j}$$

$$\boxed{u_{(i,j+1)} = \lambda u_{i+1,j} + (1-2\lambda)u_{i,j} + \lambda u_{i-1,j}} \qquad \ldots(1)$$

The above equation is valid for $(1-2\lambda) \geq 0$ (i.e) $\lambda \leq \frac{1}{2}$

When $\lambda = \frac{1}{2}$, equation (1) becomes $\boxed{u_{(i,j+1)} = \frac{u_{i+1,j} + u_{i-1,j}}{2}}$

Remark:

The solution becomes unstable when $\lambda \geq \frac{1}{2}$. Hence the next method proposed by Crank Nicolson is necessary because it does not restrict the value of λ.

Method 2: Crank – Nicolson method (or) Implicit Method

In this method u_{xx} is replaced by the average of its central difference approximations on the jth and j+1th time rows (i.e)

$u_{xx} = \frac{1}{2}\left[\frac{u_{i+1,j} - 2u_{i,j} + u_{i-1,j}}{h^2} + \frac{u_{i+1,j+1} - 2u_{i,j+1} + u_{i-1,j+1}}{h^2}\right]$ and $u_t = \frac{u_{(i,j+1)} - u_{i,j}}{k}$ the 1D heat equation becomes,

$$\frac{1}{2}\left[\frac{u_{i+1,j} - 2u_{i,j} + u_{i-1,j}}{h^2} + \frac{u_{i+1,j+1} - 2u_{i,j+1} + u_{i-1,j+1}}{h^2}\right] = a\left[\frac{u_{(i,j+1)} - u_{i,j}}{k}\right]$$

$$\frac{1}{2h^2}\left[u_{i+1,j} - 2u_{i,j} + u_{i-1,j} + u_{i+1,j+1} - 2u_{i,j+1} + u_{i-1,j+1}\right] = \frac{a}{k}\left[u_{(i,j+1)} - u_{i,j}\right]$$

$$u_{i+1,j} - 2u_{i,j} + u_{i-1,j} + u_{i+1,j+1} - 2u_{i,j+1} + u_{i-1,j+1} = \frac{2h^2 a}{k}\left[u_{(i,j+1)} - u_{i,j}\right]$$

$$\lambda\left[u_{i+1,j} - 2u_{i,j} + u_{i-1,j} + u_{i+1,j+1} - 2u_{i,j+1} + u_{i-1,j+1}\right] = 2\left[u_{(i,j+1)} - u_{i,j}\right] \text{ by taking } \lambda = \frac{k}{ah^2}$$

$$\boxed{\lambda u_{i+1,j} + (2 - 2\lambda)u_{i,j} + \lambda u_{i-1,j} + \lambda u_{i+1,j+1} + \lambda u_{i-1,j+1} = (2 + 2\lambda)u_{(i,j+1)}} \quad \ldots(1)$$

When $\lambda = 1$ equation (1) becomes,

$$\boxed{u_{(i,j+1)} = \frac{1}{4}\left[u_{i+1,j} + u_{i-1,j} + u_{i+1,j+1} + u_{i-1,j+1}\right]}$$

2.2.5 Solution of 1-D Wave Equation (Hyperbolic Type)

Consider the elastic string of length l. Let the initial displacement be f(x) and the initial velocity is g(x). Let the string be subjected to certain disturbances. This results in transverse vibrations of the string. Our objective is to find the deflection (or) displacement u(x, t) at any point x and at any time t. The mathematical model is given by $\frac{\partial^2 u}{\partial t^2} = a^2 \frac{\partial^2 u}{\partial x^2}$ $\quad 0 < x < l; 0 < t < T$. To solve this we require two boundary conditions and two initial conditions as given below,

BC: u(0, t) = 0; u(l, t) = 0 for every 0<t<T

IC: u(x, 0) = f(x); $u_t(x,0) = g(x)$ for every 0<x<l.

Derivation of finite difference formula:

(1) Consider $\frac{\partial^2 u}{\partial t^2} = a^2 \frac{\partial^2 u}{\partial x^2}$

$$\frac{u_{i,j+1}-2u_{i,j}+u_{i,j-1}}{k^2}=a^2\left[\frac{u_{i+1,j}-2u_{i,j}+u_{i-1,j}}{h^2}\right]$$

$$u_{i,j+1}-2u_{i,j}+u_{i,j-1}=u_{i+1,j}-2u_{i,j}+u_{i-1,j} \text{ by taking } a=\frac{h}{k}$$

$$\boxed{u_{i,j+1}=u_{i+1,j}+u_{i-1,j}-u_{i,j-1}}$$

…(*)

(2) Consider $u_t(x,0)=g(x)$

$$\boxed{Put\, j=0\, in U_t=\frac{u_{(i,j+1)}-u_{i,j-1}}{2k}}$$

$$\Rightarrow \quad u_{i,1}-u_{i,-1}=2k\,g(x)$$

…(**)

Also when j = 0 equation (*) becomes,

$$u_{i,1}=u_{i+1,0}+u_{i-1,0}-u_{i,-1}$$

$$u_{i,1}=u_{i+1,0}+u_{i-1,0}-\left[u_{i,1}-2k\,g(x)\right] \text{ using (**)}$$

$$2u_{i,1}=u_{i+1,0}+u_{i-1,0}+2k\,g(x)$$

$$\boxed{u_{i,1}=\frac{1}{2}\left[u_{i+1,0}+u_{i-1,0}\right]+k\,g(x)}$$

2.2.6 Solution of 2-D Steady State Heat Equation (Elliptic Type)

Type 1 (Laplace Equation)

The Laplace equation is $\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}=0$

$$\Rightarrow \frac{u_{i+1,j}-2u_{i,j}+u_{i-1,j}}{h^2}+\frac{u_{i,j+1}-2u_{i,j}+u_{i,j-1}}{k^2}=0$$

$$\Rightarrow u_{i+1,j}-2u_{i,j}+u_{i-1,j}+u_{i,j+1}-2u_{i,j}+u_{i,j-1}=0 \text{ since h = k}$$

$$\Rightarrow 4u_{i,j}=u_{i+1,j}+u_{i-1,j}+u_{i,j+1}+u_{i,j-1}$$

$$\Rightarrow \boxed{u_{i,j}=\frac{1}{4}\left[u_{i+1,j}+u_{i-1,j}+u_{i,j+1}+u_{i,j-1}\right]}$$

Type 2 (Poisson Equation)

The Poisson equation is $\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}=f(x, y)$

$$\Rightarrow \frac{u_{i+1,j}-2u_{i,j}+u_{i-1,j}}{h^2}+\frac{u_{i,j+1}-2u_{i,j}+u_{i,j-1}}{k^2}=f(ih,jk)$$

$$\Rightarrow \frac{u_{i+1,j} - 2u_{i,j} + u_{i-1,j}}{h^2} + \frac{u_{i,j+1} - 2u_{i,j} + u_{i,j-1}}{h^2} = f(ih, jh) \text{ since h = k}$$

$$\Rightarrow \boxed{u_{i+1,j} + u_{i-1,j} + u_{i,j+1} + u_{i,j-1} - 4u_{i,j} = h^2 f(ih, jh)}$$

2.3 Finite Element Method

FEM is a numerical method in which continuous physical systems are discretized into simple geometric shapes called finite element. Discretizing means modeling a body by dividing it into an equivalent system of finite elements interconnected at a finite number of points on each element called nodes. Applications of FEM in structural problems include Buckling problem, Stress Analysis, Vibration Analysis and Impact Problem. Fluid Mechanics, Heat Transfer and Electric or Magnetic Potential are examples of non-structural Problems.

2.3.1 Analytical Processes of Finite Element Method

Structural Stress Analysis Problem

The conditions like Equilibrium, Constitutive law, Compatibility and Boundary conditions are used to represent the system behavior as a system of equations. The two approaches available are Force (flexibility) method in which internal forces as considered as unknowns and Displacement (stiffness) method in which the nodal disp are unknowns. Due to simplicity in formulation the displacement method is more desirable than force method. Many Finite Element softwares have incorporated the displacement method for solving structural problems.

Analysis procedures of linear static structural analysis

- Identify the geometrical model as 1D, 2D or 3D.
- Discretize and select the element type.
- Select a shape function
- Define the compatibility and constitutive law

  $1D : \frac{du}{dx} = \varepsilon x$ and $\sigma = E\varepsilon$

- Form the element stiffness matrix and equations by Direct equilibrium method, Work or energy method or Method of weight Residuals.
- Assemble the element equations to obtain global system equation and introduce boundary conditions.
- Solve the system equations using Gauss Elimination method or Gauss Iteration method.
- Interpret the results using deformation plot or stress contour.

Computer Programs for Finite Element Method are ANSYS, NASTRAN, ABAQUS, MARC and COSMOS.

2.4 Discrete Element Method

Engineers and scientists want to predict the mechanical behaviour of materials. DEM is a method to study such a behavior of granular materials and structures comprising of smaller components like bricks, grains etc… In this method we apply repeatedly Newton's second law and force displacement law. The usual calculation techniques like FEM or finite difference methods are unable to reflect directly the behaviour of materials. For this reason engineers started searching for alternative modeling technique.

From 1990, DEM became an important tool for modern engineers. Due to the development of computer softwares the realistic problems could be readily analysed on computer in reasonable computational time.

Modifying the definition of Cundall and Hart (1992), a numerical model is said to be a discrete element model if

- It consists of separate, finite-sized bodies each of them being able to displace independently of each other;
- Larger displacement of the elements are allowed (i.e. not infinitesimally small);
- The elements that come into contact with each other are automatically detected while performing the calculations.

The ability of the elements to move independently of each other is a basic difference from FEM where different continuity conditions have to be satisfied at the common nodes of neighbouring elements. In addition, while several FEM, frame or fracture mechanical software are able to simulate the separation of elements, a DEM code must possess the ability to handle contact creation too. In modern DEM investigations the individual particles may be made breakable (e.g. McDowell and Harireche, 2002; Cheng et al, 2003): they can fall into their components or groups of components under suitable mechanical conditions.

2.4.1 Algorithm of DEM

1. Initial positions, orientations and velocities are found.
2. Update particle link – list(find new or broken contacts).
3. Calculate force and Torque on each particle. Eg: For spheres $F = ma$ and $T = I\alpha$.
4. Integrate equations of motion to find out new positions, orientations and velocities.

5. Accumulate statistics to calculate transport properties.
6. Time increment $t = t + dt$.
7. Repeat steps 2 to 6.

The softwares designed for DEM are BALL & TRUBAL, YADE, MFIX-DEM, PFC2D, PFC3D, EDEM, LIGGGHTS and Mercury- DPM.

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A Review on D.I. Diesel Engine using Solenoid Operated System

[1]S. Sivananthan, [2]B. Prakash, [3]S. Gnanasekaran,
[4]C. Samson Jerold Samuel

[1,2]Assistant Professor, Department of Mechanical Engineering, K. Ramakrishnan College of Engineering, Samayapuram, Trichy – 621112.

[3]Assistant Professor, Department of Mechanical Engineering, Sri Shakthi Institute of Engineering and Technology, Coimbatore, Tamilnadu, India – 641062.

[4]Associate Professor, Department of Mechanical Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, Tamilnadu, India – 641008.

Introduction

In four stroke internal combustion engines, the valves control the gas inlet and outlet events. Solenoid valve operated (SVO) systems perform the required valve timing independently of the crankshaft position. With this feature, SVO systems have a great potential for increasing engine performance, ensuring optimum fuel consumption and minimizing emissions. The intent of this investigation is to improve an SVO system, which has 24V supply potential, and to investigate engine performance at different lifting valve operations and then to determine the support limits of an internal combustion engine. At the end of the development of the SVO system, the transition time for 6mm valve lift is measured as 50 ms. accordingly, it will be evaluated that a four-stroke internal combustion engine can be supported up to 2128 rpm. The present analysis evaluates solenoid operated diesel Engine. A single cylinder Diesel Engine adapted to study the Brake thermal efficiency, Brake specific energy consumption, and emissions in Low Cetane fuels. In this study, the diesel engine will be tested using Diesel with and without the solenoid operated valve. From this study the emissions like HC and CO is to be evaluated. The results will be comparing with conventional cam operated engine.

Combustion and Emission of Conventional Vs Camless Engine

This graph provides a detailed information of combustion of the conventional engine and camless engine, where the brake thermal efficiency gradually increases

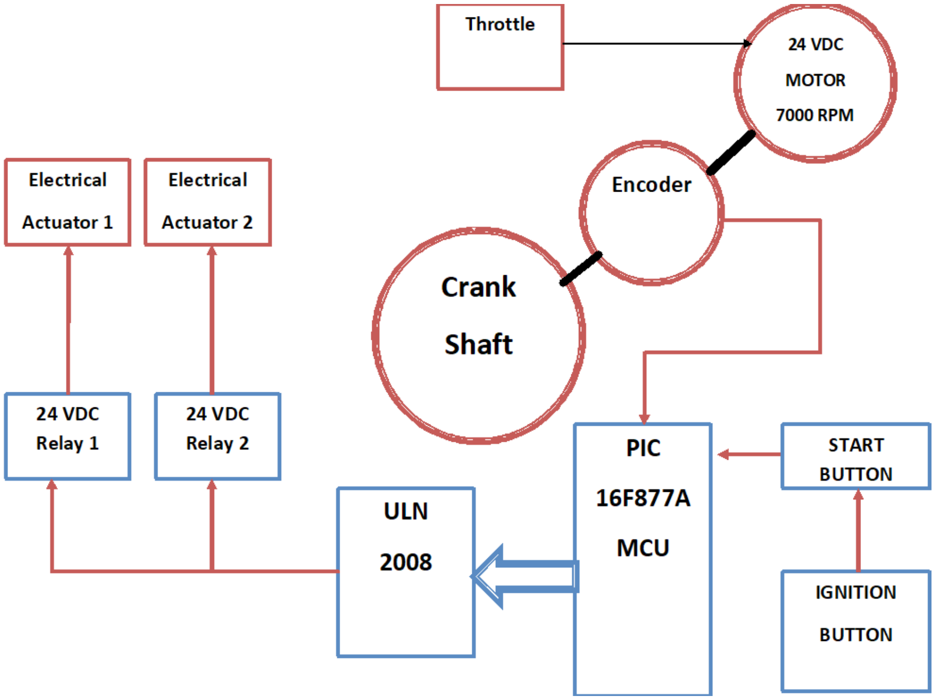

Fig. 1: Design and circuit diagram

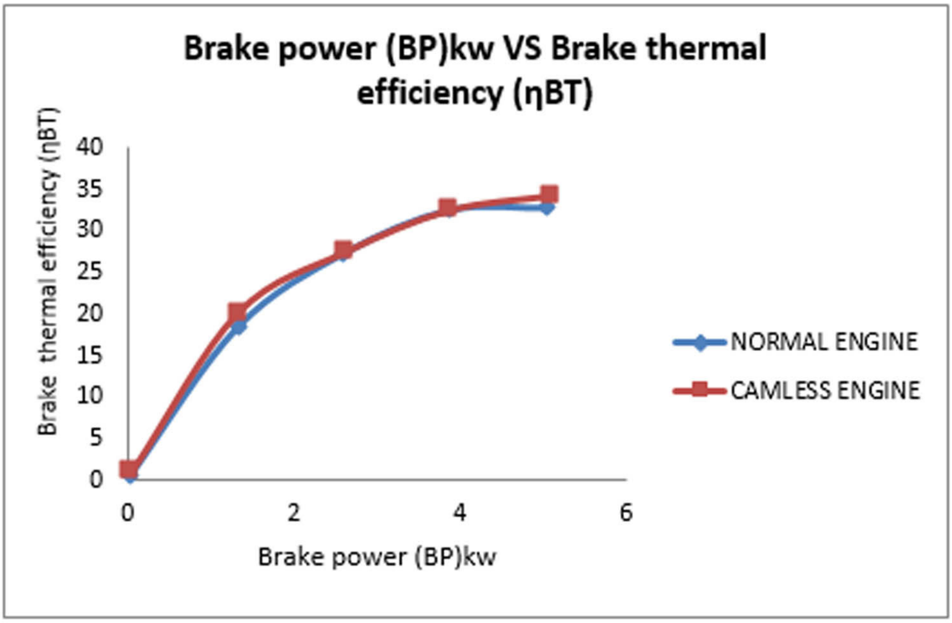

Fig. 2: BP vs Brake thermal efficiency

with brake power for the camless engine when compared to conventional engine. Due to the fast actuation of the intake valve makes higher amount of air mass takes place increases the swirl force and high pressurized temperature inside the cylinder induces the better mixture with high pressurized fuel in the combustion chamber well converts the heat from a fuel to mechanical energy.

This graph clearly shows that, with the delivered brake power the carbon monoxide emission increases due to air deficiency cause the incomplete combustion and where the oxidation process does not occur completely for conventional engine. In the electromechanical actuator system by the developed valve actuation improves the complete combustion leads to high air presence, the oxidation process tends to occur makes most of the carbon to CO_2. This provides the reduced amount of carbon monoxide emission in camless engine. A high carbon monoxide emission in the cam engine and low in camless engine by using of this solenoid valve actuation system.

This graphs says that the result of brake power and specific fuel consumption slightly changes and most of them are equal in cam engine and camless engine. This indicate that the camless engine gives almost similar efficient as compared to the conventional engine.

Brake Power and Carbon dioxide graph 6.4 shows that by changing the valve train shows that the carbon dioxide deceases in the camless engine. CO_2 is produced from the combustion of fuel containing carbon. The carbon combines with oxygen

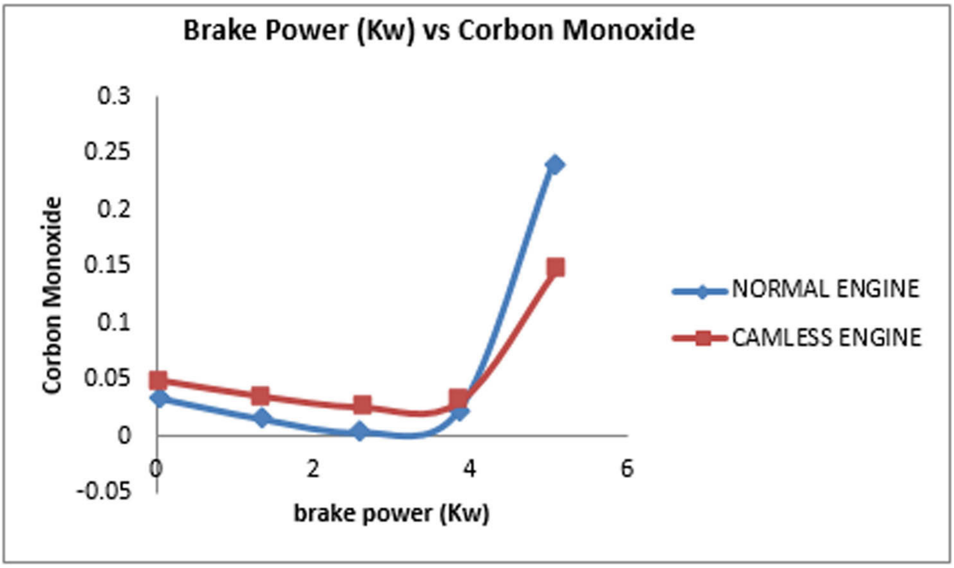

Fig. 3: BP vs CO

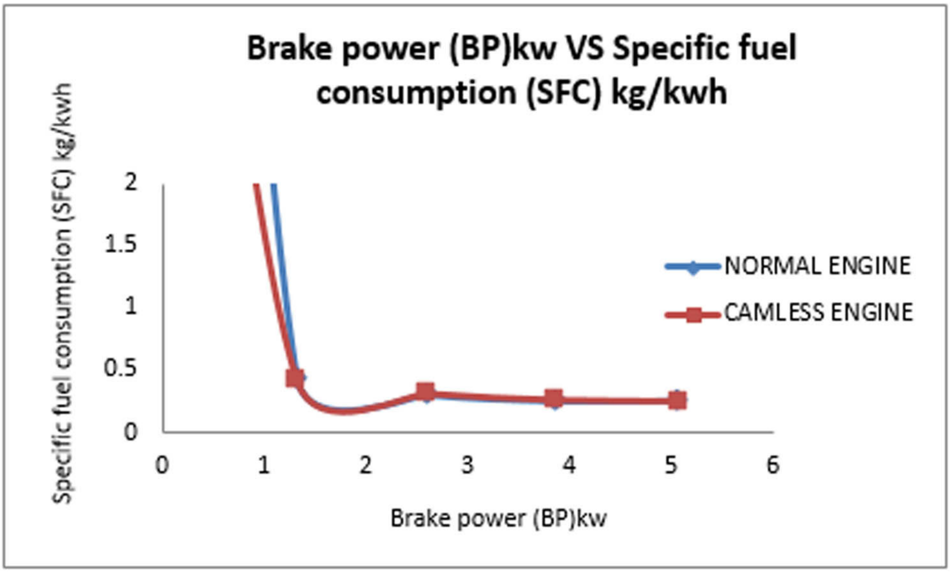

Fig. 4: BP vs BSFC

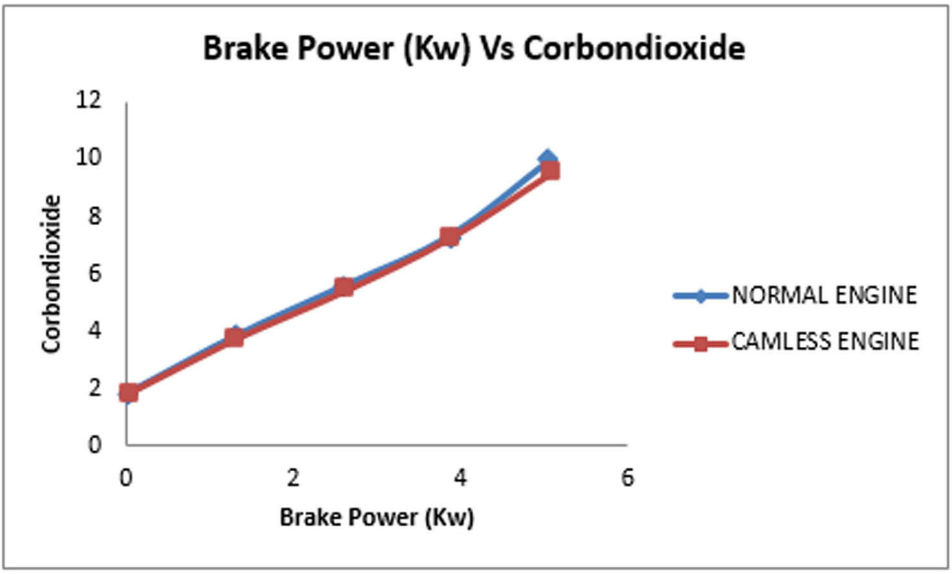

Fig. 5: BP vs CO_2

induced into the engine. The carbon dioxide emission can be lowered by using the high compression ignition technology. In this graph CO_2 the normal engine shows in the rate of 10 and solenoid powered camless engine decreased at the rate of 9.

Table 1: Camshaft engine emission report						
CO	*HC*	*CO_2*	*O_2*	*NOX*	*Lambda*	*Opacity*
%	*PPM*	*%*	*%*	*PPM*		*%*
0.049	11	1.84	18.12	146	7.704	1.9
0.035	13	3.72	15.45	542	3.88	7.1
0.025	16	5.39	13.06	1258	2.688	18.6
0.03	22	7.22	10.51	1829	2.013	33.5
0.147	36	9.53	7.19	2017	1.512	60.5

Table 2: Camless engine emission report						
CO	*HC*	*CO_2*	*O_2*	*NOX*	*Lambda*	*Opacity*
%	*PPM*	*%*	*%*	*PPM*		*%*
0.034	17	1.85	18.13	163	7.714	0
0.016	22	3.85	15.11	715	3.732	2.8
0.004	27	5.57	12.56	1351	2.576	14
0.024	36	7.32	9.9	1824	1.94	26.7
0.239	45	9.96	6.03	2023	1.402	61.8

Conclusion

The concept of variable valve actuation has been performed by replacing internal combustion engine's camshaft valve train with an electromechanical controlled, solenoid actuators. Initial development confirmed its functional ability to control the valve timing, lift, velocity, and event duration, as well as to perform selectively variable deactivation in a four-valve or two valve engine. The electromechanical valve train is integral with the cylinder head, which lowers the head height and improves the engine packaging. Valve stroke requirements have been achieved some improvement and, at some input variations, have been exceeded. Performance and emission testing has shown some limitations related to the flow rate and input waveforms. However, the carbon monoxide has been controlled and, it is these limitations that have provided the inspiration for continued development and discovery. Further research and development are needed to take full advantage of this system exceptional flexibility.

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The Effect of Friction Stir Processing on the Microstructure and Mechanical Properties of an AA5086 Alloy

[1]Libin Yohannan K, [2]M.S Senthil Saravann, [3]Hafeer Mohammed, [4]Sreejith Mohan

[1-3]Department of Mechanical Engineering, Sree Buddha College of Engineering Pathanamthitta
[4]Department of Mechanical Engineering, National Institute of Engineering, Mysore
e-mail: libinyohannank@gmail.com

ABSTRACT

In the present work, friction stir processing (FSP) is employed to change the surface properties of aluminium. Aluminium AA5086 is taken for the present study. Friction stir processing is done on PAOFONG vertical milling machine by hardened steel tool with tip diameter of 2 mm. The spindle speed is 1480 rpm with feed rate of 1mm/min and depth of cutting is 2mm. the hardness of the samples were measured using micro hardness test. It is found the hardness of friction stirred aluminium is higher than the base aluminium alloy. The tensile strength of friction stir processing was increased compared to the base metal. The microstructure of the stir zone was analyzed using XRD, SEM tests.

1. Introduction

Friction stir processing (FSP) is based on the principle of friction stir welding technique (FSW) invented by The Welding Institute (TWI) in 1991. Friction Stir Processing (FSP) is a technique of solid-state processing used as a material joining tool and as a surface processing tool. The material's melting temperature attained a high temperature where severe plastic deformation A rotating tool is done along a specified path through a fixed workpiece material as shown in Fig1.1. The Friction Stir Processing (FSP) tool usually consists of a cylindrical shoulder and a concentrate pin given the successful use of the off-axis pins. The tool's pin is forced into the workpiece and increases the welded or processed zone's penetration depth. The tool serves two main functions: (a) heating of the workpiece and (b) movement of the joint manufacturing material. The friction between the tool and the deformation of plastics. Localized heating makes the material around the pin softer and the mixture of tool rotation and material motion from the front of the pin to the back of the pin. When the solid is deposited at the top of the work piece rotating the tangential velocity of the tool, the material flows around the pin supporting its forward motion of the retreating part of the tool (Fig. 1.1). On the forward side, the tangential velocity of the instrument is in the same direction as the instrument feed. The tangential velocity of the rotating tool is opposed by the stationary specimen that modifies the microstructure of processed metallic components in near-surface layers. In specific, fine grain structure can be produced

- Surface Composite
- Microstructural modification of cast alloy
- Alloy with specific elements

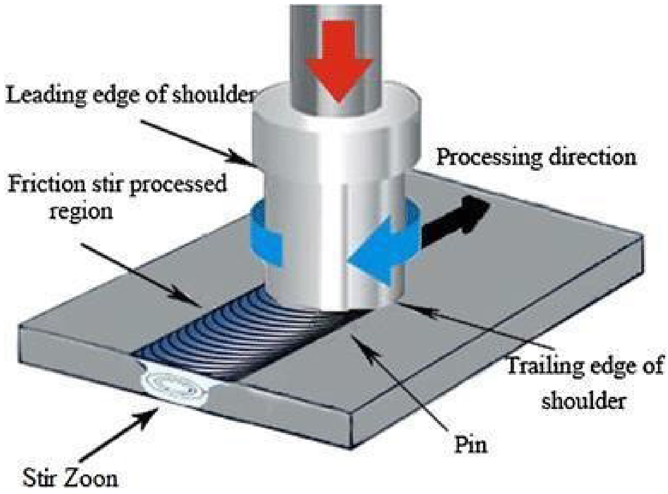


Fig. 1.1: Process and the mechanism of friction stir processing

The Friction stir processed (FSP) surface is divided into four areas. The first is the material or parent metal affected that is a material remote from the weld that has not been deformed and is not affected by heat in terms of micro-structure or mechanical properties, although it may have experienced a weld thermal cycle. Secondly, in this zone, which is closer to the center, the heat-affected zone the material has undergone a heat cycle that has altered the microstructure and mechanical properties. In this region, however, there is no plastic deformation. The third zone is the Thermo mechanically affected zone (TMAZ)) where the FSP tool has plastically deformed the material in this region and the heat from the method will affect the material also. In the case of aluminum, significant plastic strain can be obtained without recrystallization in this region, and there is generally a distinct boundary between the recrystallized zone (nugget) and the deformed zones of TMAZ. Finally, the Finally, the Fourth region is characterized as the nugget: the completely recrystallized area, sometimes referred to as the stir zone, relates to the area originally occupied by the key. The word stir area is frequently used in friction stir processing, where large amounts of content are processed.

2. Design of Tool Geometry

It is possible to divide the non-consumable stir tool used in FSP processes into two categories: tools with pins and pin-less tools (Fig2). Of these, pin tools are used more widely and pin-less tools are usually used to modify material surfaces or encapsulate improved particles during the processing of composites. The size of the tool and the shape of the pin have a huge effect on the heat manufacturing and fabric glide for the duration of Friction Stir Processing (FSP) processing. When a tool with a larger shoulder diameter is used, the friction warmness is greater focused, and the cloth plastic deformation is extra intense. This results in a stable micro structure and a higher refinement of 2nd segment particles. Studies on the impact of pin profiles on warmness technology during the plunge degree show that an powerful tool pin place plays a key role within the friction deformation and warmth manufacturing; subsequently, the temperature in the course of the plunge stage is lowest with using a conical pin.

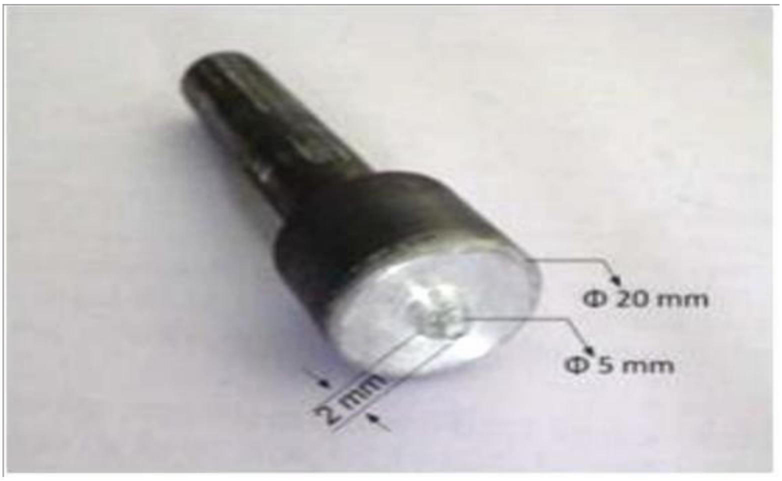


Fig. 2.1: Friction stir processing (FSP) rotational tool

The tool's material is available in rod. The geometries of the cylindrical tools were generated according to the designated sizes using the turning machine. Fig. 2.1 provides the tool specifications and parameters.

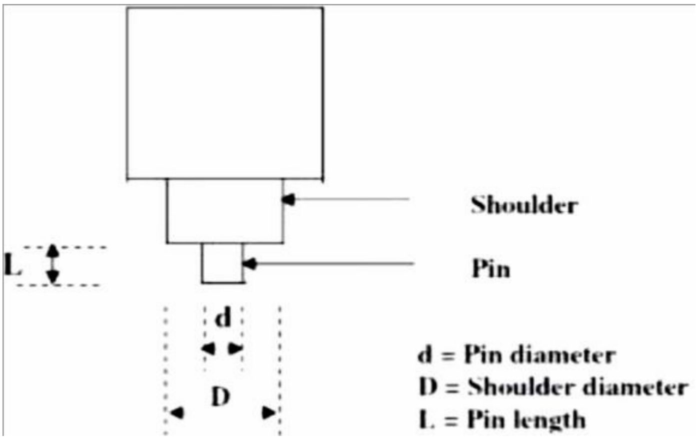
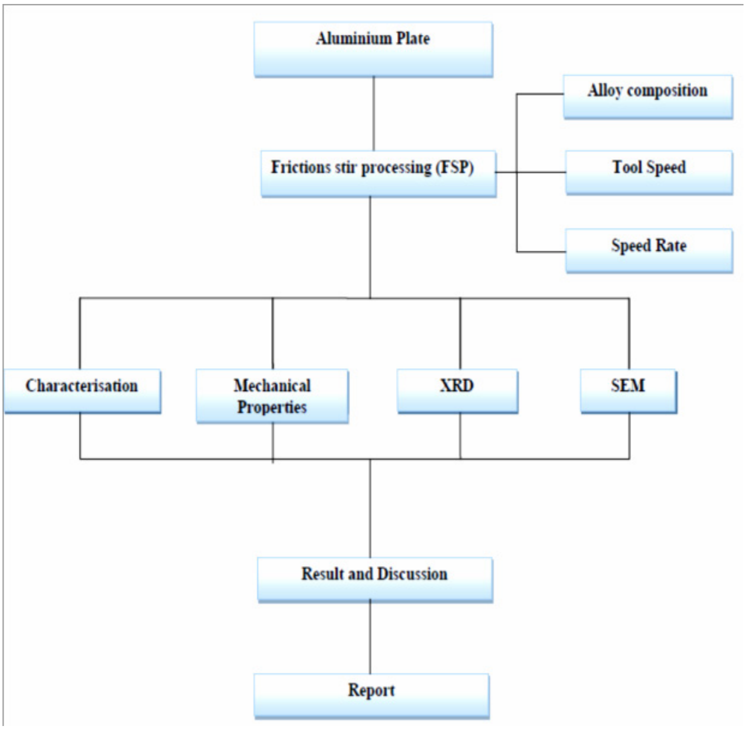


Fig. 2.2: The details of size of friction stir processing (FSP) rotational tool

3. Methodology



A manual vertical milling machine (made by PAO FONG) is used for Friction Stir Processing (FSP). Feed rate 1mm/mint, tool speed 1480 rpm and depth of cutting was 2mm, single pass Friction Stir Processing (FSP) was done. Tool used for Friction Stir Processing (FSP) was fabricated using mild steel. The geometry of tool in shown in fig. tool was prepared as per the geometry and heat treated at 400˚ c following by oil quenching. The hardness of the tool was measured which is equivalent tool steel. The fabricated tool is used for Friction Stir Processing (FSP).

4. Working Procedure

A specially designed non-consumable cylindrical tool is rotated and plunged into the selected area to friction the required location within a plate or metal. Tool has a small diameter pin with a concentrated larger shoulder, the penetration depth is regulated by the tool shoulder and the entrance probe length. When the tool descends to the part, the rotating pin contacts the surface, rapidly produces friction between the tool pin and the metal surface heat and softens a small metal column, the rotating tool provides:

When the shoulder contacts the metal surface, its rotation creates additional frictional heat and plasticizes a larger cylindrical metal column around the pin inserted. The shoulder also provides a forging force that contains the upward metal flow caused by the tool pin, During Friction Stir Processing (FSP), the work piece and the tool are moved relative to each other so that the tool traverses, until the required area is processed. The processed zone cools, without solidification, as there is no liquid, forming a recrystallized, fine grain microstructure. The processing specimen were analyzed by microstructure and mechanical properties.

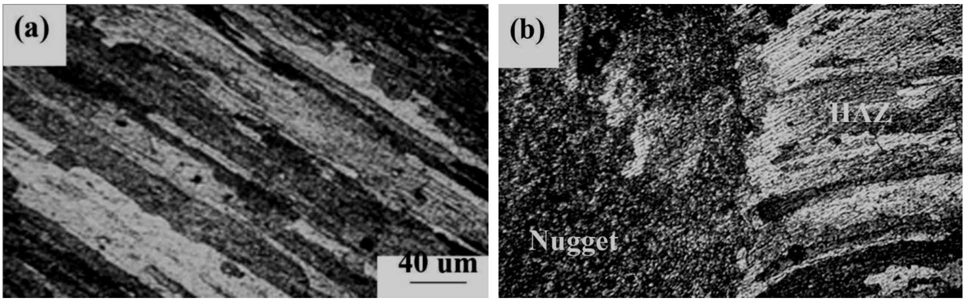
5. Result and Discussions

Microstructure

The microstructure of base and FSP AA 5086 samples are shown in Fig. 5.1. The base samples shows equiaxed dendrite like deformed structure shows the Magnesium regions.The combination of squeezing pressure and rapid rotation during friction stir processing leads to frictional heating and softening of the sample's faying surfaces. It may be possible to melt due to high temperature, but it can not be seen. The high heat lowers the materials ' flow strength by closing atoms causing fine grains. In FSP, there is more heat transfer rate affecting the surface adjacent to the nugget. The surfaces affected are classified into the affected thermo-mechanically zone (TMAZ) and the affected heat zone (HAZ). In TMAZ there is a mixture of fine and large grains, whereas in HAZ there is a large growth of grains due to high heat transfer. In FSP, there is more heat transfer rate affecting the surface adjacent to the nugget. The surfaces affected are classified into the affected thermo-mechanically zone (TMAZ) and the affected heat zone (HAZ). In TMAZ there is a mixture of fine and large grains, whereas in HAZ there is a large grain growth due to a high heat transfer rate.

Processed zone samples of the base metal optical images and of the Friction Stir Processing (FSP). It was observed that the grain size was finer compared to the base metal Fig 5.1(a) in the Friction Stir Processing (FSP) samples. Compared to the base metal, the Friction Stir Processing (FSP) samples. The AA5086 alloy received had an average 10 mm grain size. Due to the dynamic recrystallization process that took place during Friction Stir Processing (FSP) Fig, very fine equiaxed grains were observed in the nugget zone. 5.1(b).

Friction Stir Processing Friction Stir Processing (FSP) process is the creation of a transition zone (TMAZ) between the parent material and the nugget zone. During Friction Stir Processing (FSP), TMAZ experiences temperature and deformation. The thermo- mechanically affected region (TMAZ) is characterized by a highly deformed structure. The parent metal's elongated grains were deformed in a pattern of upward flow around the nugget zone. Although plastic deformation occurred in the thermo-mechanically affected region (TMAZ), recrystallization did not occur in this zone. Due to insu fficient stress of deformation. However, dissolution of some precipitates was observed in the thermo-mechanically affected zone (TMAZ) due to high-temperature exposure Friction Stir Processing (FSP). Generally, the extent of the dissolution depends on TMAZ's thermal cycle. It was also revealed that the grains in the thermo-mechanically affected zone (TMAZ) usually contain a high sub-boundary density and a heat-affected zone (HAZ) exceeds the thermo- mechanically affected zone (TMAZ) Figure 5.1(b). There is a thermal cycle in this zone, but there is no plastic deformation. The distribution of precipitates in the grain boundaries has been reduced due to dissolution. This means that the heat-affected area (HAZ) has the same grain structure as the parent material.



Optical Microstructure: Base Metal

Optical Microstructure: FSP samples

Micro Hardness

Aluminum alloy hardness can generally be improved by several techniques: solid solution hardening, grain refining strengthening, work or strain hardening, and precipitation (aging) hardening. Changes in aluminum alloys heat-treatable (precipitation-hardened) and non-heat- treatable (solid-solution-hardened) may be distinct during Friction Stir Processing (FSP). Friction Stir Processing (FSP) generally does not result in sample softening for solid- solution-hardened aluminum; in the processed zone, the hardness profile was roughly uniform; however, it was slightly higher than that in the base material. In this work, the hardness profile is mainly affected by dislocation density, as the main hardening mechanism for AA5086 is strain hardening. The average hardness value for the grain refinement zone in the nugget was around 77 HV due to the strain hardening mechanism, which shows a smooth increase from the hardness of base metal 51 HV. There is only a slight decrease in hardness observed in the HAZ region on both advancing and retreating sides. This decrease occurred in this region as a result of the thermal cycle during the process. Therefore local softening was observed on both sides of the processed zone.

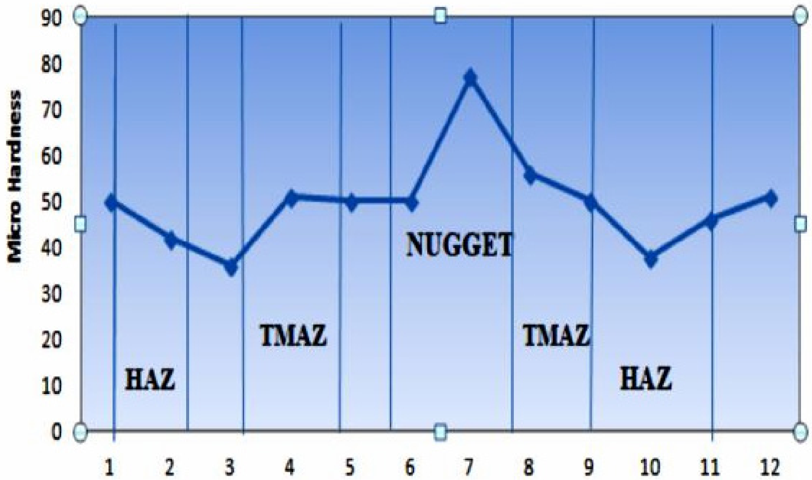


Fig 5.2: Micro hardness profile of the processed zone

Tensile Test

The preparation of the schematic specimen from the processed zone of friction stirs Fig 5.4. Tensile specimen sizes were determined in according with the ASTM E8-08 standard 50 mm (complete length), 12 mm (width) and 30 mm gauge length Fig 5.5. Specimens of longitudinal and transverse tensile were prepared.

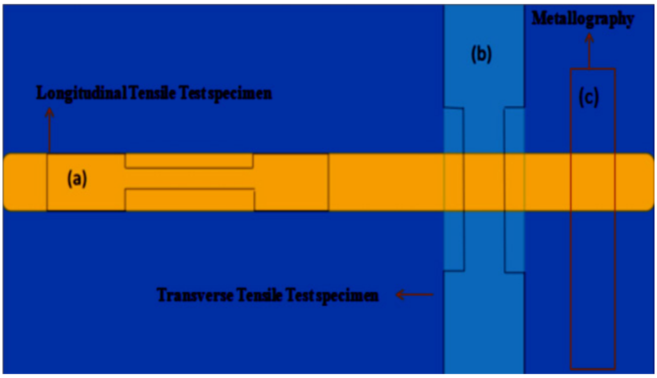


Fig. 5.4: Schematic illustration of the specimen preparation from the friction stir processed zone

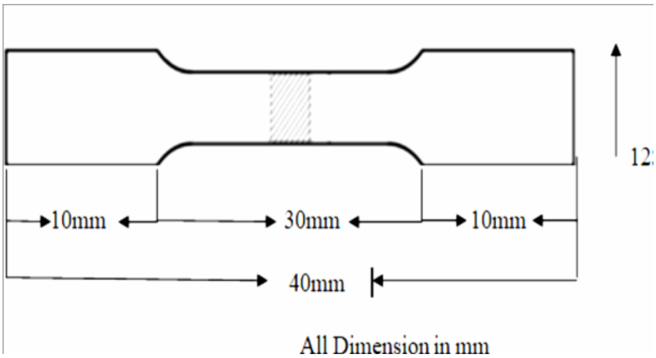


Fig. 5.5: Size of samples used for tensile test

- Sample (a) shows normal tensile curve as like ordinary aluminum with more ultimate strength fig 5.6
- Sample (b) shows an normal in tensile behaviour. The graph resembles like mild steel which proves the hardness is more and failure is ductile to brittle transition failure in longitudinal tensile test friction stir process sample fig 5.7

Scanning Electron Micrographs (SEM)

Figure 5.9 shows that the SEM fractography. Base Metal and Friction Stir Processing samples. The Base Metal shows the mixture of eutectic cleavage and dimple morphology. It can be seen the some eutectic Mg and Cu particles pull-out from the surface. This elongated pull-out is the main source of stress concentration factor and leads to fracture. Their exist some dendrites structure which behave like grains. This strong interaction between the particles and slip band. Generates stress concentration during plastics deformation. The final fracture of the samples passes

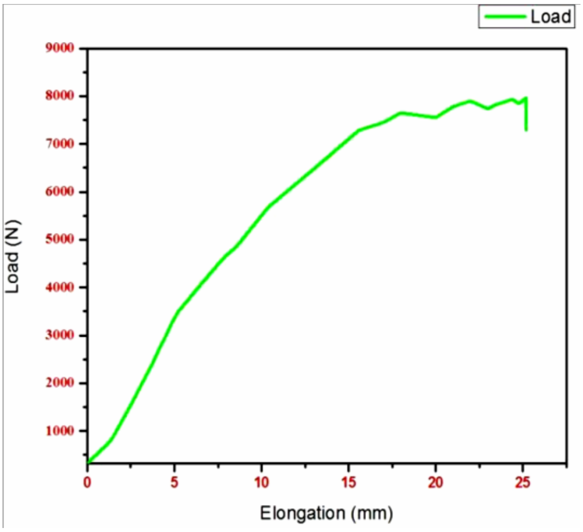


Fig. 5.6: Transverse Tensile test of friction stir processing specimens

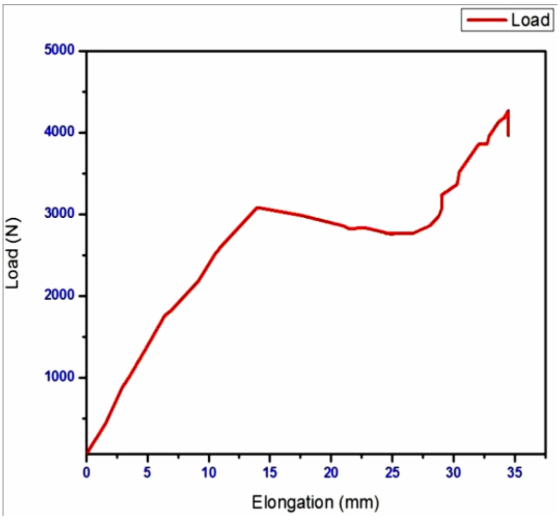


Fig. 5.7: Longitudinal Tensile Test Friction Stir Process Sample

through the eutectic region or phase and generated the formation of flat area. As a result, the tensile fracture shows the transverse granule the fracture nature. The tensile of Al-Mg samples can be explained by SEM image are shown in Fig5.8. The fractography clearly show the large dimples and cavities, which indicates the ductile fracture. The dimples are fine and processing less cleavage than Friction Stir Processing (FSP).

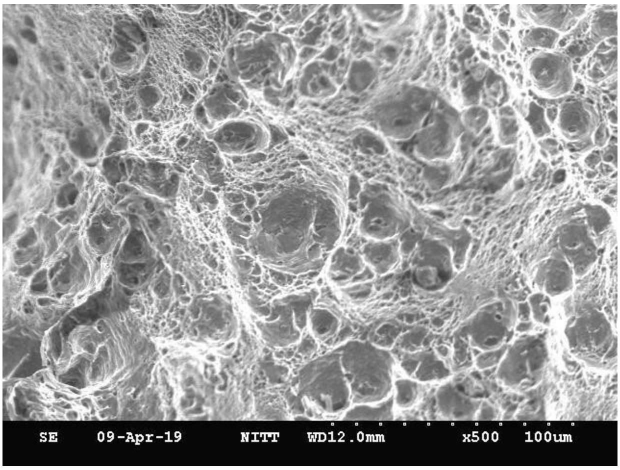


Fig. 5.8: SEM image of base metal

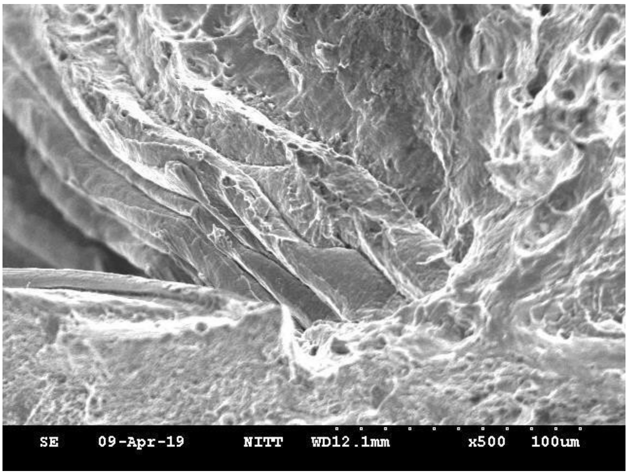


Fig. 5.9: SEM image of FSP zone

5. CONCLUSION

Aluminium alloy AA 5086 was taken for the investigation. The alloy samples were Friction Stir Processing (FSP) for the analysis of microstructure and mechanical properties.

- To developed a modified setup for friction stir processing (FSP)
- A single Friction Stir Processing (FSP) pass resulted in a significant grain refinement in AA5086.The microstructure is characterized by equiaxed fine grains with well- defined grain boundaries.

- The microstructure developed through the method of dynamic recovery and dynamic recrystallization.
- The strength of the Friction Stir Processing (FSP) material improved significantly and at the same time the ductility was not retained.
- Hardness has also substantially improved.

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Project Management in GSD Environment

Dr. S. Ramacharan

Associate Professor, IT Department
G. Narayanamma Institute of Technology and Sciences, Hyderabad
Mail id: s.ramacharan@gnits.ac.in, s.ramacharan@gmail.com

ABSTRACT

One of the most exceptionally important tasks in software development life cycle is to produce precise effort estimations and schedule. Effort estimate is used as input to project planning, budgeting, pricing policies and investment analyses by the developers. Missing or Incomplete data are exasperation to a certain extent everywhere but especially in effort estimation it is a greater hindrance. Over estimation of the software effort can result in losing the chance to win a bid and underestimation can lead to detrimental effect on the quality of software or monetary loss. Accuracy in effort estimation is decisive for developers and customers also it is required to do preplanning, budgeting, risk analysis and productivity assessment and customers requires estimation for taking place in contract negotiation process by the developers. Accuracy of data during effort estimation is termed as the characteristics of the dataset and it is a great deal of uncertainty in such datasets. Quality of data is the major challenge in Software estimation because missing values leads to High degree of inaccuracy and the missing value is commonly measured to ignore the whole project data or its feature. All the popular empirical estimation models require accurate inputs for estimation of effort or in other words, the accuracy of the output of these models is depends upon the accuracy in the input parameters. It is very difficult to obtain such accurate information at the early development stage of a software project. Controlling the huge uncertainty in existing estimation model is hard since it could not be modelled purely based on mathematics. These issues led to the introduction of variety of techniques to solve the relevant issues of effort estimation in GSD projects. The objective of this chapter is to identify what are the factors that will have major impact in GSD projects and how to overcome these factors while calculating effective estimation for a GSD projects.

Keywords: Effort Estimation, GSD (Global software development), socio-cultural distance, Geographical distance, Critical Success Factor (CSF)

1.1 Introduction

Global Software Development (GSD) has grow to be a one of the major business need internationally worldwide which is been previously cited to be off shore development, Software development over Internet, multi-site software development, distributed software project development.

Global Software Development assumes and follows sun rule i.e exploit the Complete time for the software project development therefore GSD is also called no sun set in software development[1] GSD has three distinct but complementary perspectives: Business perspective, Socio Economical perspective and Technical Perspective. The incident of Global Software Development (GSD) is taking possible and the implication of GSD boost with the course of time. GSD offers highly skilled personal with low cost. It is one of the reasons behind shifting software industry from co-located development to GSD. This shifting brought some new challenges in software development. The problems arising from the geographical, temporal and socio-cultural distance are the main challenges for GSD. Lack of formal communication generates misunderstandings in requirements or changes in the requirement specification. Real time contact between the distributed team is more difficult with temporal and geographical difference. Socio-cultural difference leads problems, such as, different opinions about the nature of the software development process.[9] Language problem also discourages employees to online meeting. To avoid this fear he/she prefers to asynchronous communication e.g. email etc. However, sometime one cannot express a problem through only words; he needs gesture. Body language and pitch. Moreover, the distance and complexity of coordination is directly proportional. As distance increases, the complexity of coordination increases in software development process. This complexity also arise lack of familiarity with remotely located colleagues and increase in communication cost as well. Apparently, trust and teamwork cannot take birth in this situation. GSD environment erg to reduce these complexities also needed to enhance the ability to focus on coordination of resources. It is important to overcome these challenges in development and also essential to offer generic solutions to these challenges.

1.1.1 GSD

The software development process is determined as a collection of actions, procedures, practices and technologies which is used by people and companies for software development and to maintain associated software and products. The main concern in the software development process is established on the following basis: – The quality of the software mainly dependent on the quality of the process used. It is possible to define, manage; measure, as well as software process can be improved. Even though if well defined software process is used it is not that much simple to develop software. The GSD is characterized based on how the development team geographically distributed on a worldwide scale which leads to computation of globalization of efforts required. Majority of GSD projects fails due to varying estimates which is available widely so software development filled with many difficulties. The record of descriptions that differentiate GSD from normal (centralized) development is small and specific: distance (the distance between developing team scattered from each other and these developers from their customers or end users); time-zone differences (time zone mainly a puzzling factor with distance); and national culture (it comprises language barrier, traditions, custom). These three parameters will have major effects on various levels:

- **Strategic issues**: The choice whether a software project should be developed by globally distributed teams, where this software project can be better developed, and how this software project to be divided across multiple sites is a toughest task. Many analyst expressed options about the risks and benefits of global project development. This GSD development depends upon resources availability at different sites, degree of expertise in technology, infrastructure required for development so on. Many appropriate models are essential under various circumstances.
- **Cultural issues**: In Global Software development there is a need for close collaboration between individuals with diversified cultural backgrounds. Culture differs in many dimensions from national, ethnic, professional so on. Many people find such differences which leads to severe and persistent misunderstanding. For example, e-mail in some culture may be offensive for someone with different background. Culture differences frequently intensify communication problems.
- **Knowledge management:** The advantages of GSD benefits cannot be explored if there is no valuable information and knowledge-sharing mechanisms among the people. Even substandard documentation can also leads to unsuccessful collaborative development. Generally documentation depends on confrontation among developers but in context of Global Software Development the effectiveness of documentation is vital for all aspects such as required to simplify unspoken inference and doubts, and to support maintainability.
- **Technical issues:** When various teams work on different sites then one of the crucial problems is lack of synchronization among them. So there should be uniform milestones between the members and clear entry point and exit point for every task. Naturally, risk management has not taken into account possible influence on the distribution, dissimilar cultures, schedule and outlook. The overheads for software projects are amazing related to control and coordination. Due to the differences in distance in GSD project neither

people cannot synchronize by glance between compartment walls nor will managers have a control by visiting the team's office. In addition, time zone differences can be resolved related to issues or algorithm clarification on fly by a quick phone call. Ever since networks traverse globally distributed places are frequently sluggish and untrustworthy. So the tasks that require broadcasting vital data must be thoroughly designed and executed for example in case of configuration management it is very essential and important. In case of GSD projects it is important to control product changes and also ensure all the concerns related to the project. Many tools and techniques have been developed in GSD environment to control and coordinate the development teams working. Majority of these tools focus on formal communication and non interactive communication channels. The conventional problems and existing challenges of GSD can be summarised as follows. Companies are searching for aggressive benefits in development in terms expenditure, quality and flexibility, gazing for increased productivity and reduced risk. Most organizations are forced to explore the competitive benefits for global solutions. There are two major choices at present employed: offshore outsourcing and offshore in sourcing.

1.1.2 Insufficient Communication

Initial stages of software development require a large amount of healthier communication. Software projects require two Communication needs such as a clear formal, official communications and well-understood interface. In critical tasks If the interface is designed badly there is a threat for time lose and also task descend through the cracks. Vital communication channel can be surprisingly disabled during development such that developers not situated jointly will have less informal, impulsive transformation across sites. Informal transformations helps people in knowing what is progressing around them, what other individuals are doing in the project, what represents different fragments of the project are in, who has knowledge and skills in which area, and several other necessary information that facilitate developers to work together efficiently. One of the issue produce for any software project is extended periods. The deficiency in ongoing conversation from multiple sites results in misalignment and rework. Basically if the project is unsure then communication channel plays a vital role and becomes more important. These affairs are even more composite in case of outsourcing arrangements. In many cases restricted or filtered communication is used due to the fear of losing intellectual property or other proprietary information concerned to product or schedules. This frequently damages this critical channel.

1.1.3 Issues Related to Project and Process Management

When teams accommodating processes will have deficiency in synchronization between sites will be critical for example, if the team at one location and the test group at another location if they define unit-tested code in a different way. Synchronization requires uniform milestones and a precise entry point and exit point criteria. Although concurrent development process models suggested in the literature and they are used, in Global Software Development it is very difficult for developing effective concurrent engineering philosophy due to unpredictable requirements, unbalanced specifications, and the lack of good tools which support collaboration across schedule and space, and deficiency in of informal communication. In few cases they practice risk management in a conventional fashion, not considering the probable encounters of diverse cultures and attitudes.

1.2 Project Management in GSD

Because of time zone, geographic and communication differences, the project management is now a great challenge in GSD. Project management seems to be same entity for both co-located and GSD environment and, an experienced project manager can set the project on the success path.[1] Some concealed risks sway project's success. Project managers are advancing and updating themselves according to the new paradigm of GSD. Both (literature and industry) are lacking to provide the standardized approaches. Sights of GSD process management and problem solution. Some generic problems and hurdles need to solve and remove. According to conclusion about global project management, it is recommended to overcome problems of communication maimer. Employees also hesitate to adopt new means of interactive communications. Switching the personnel between their partners according to task distribution causing problems associated with wrong approach in project process distribution that affects the overall result of the project. There are also some problems of unclear-shared goals in the GSD environment. A project manager has to share this knowledge with the employees and the organizations. Effort estimation[3] is one of important activity of project management. It is closely associated with risk management.[4] For GSD project, risk management requires more intension because there are some additional GSD factors involved. GSD factors, e-g multi sourcing, geographical distribution, temporal diversity, socio-cultural diversity, linguistic diversity, contextual diversity and political and legislative diversity are the main roots for GSD threats that imperial the success of global project. These threats are directly affect the GSD project management activities.[9] These threats reveal the weird nature of GSD project. They also generate a force that develops obstacles in a project.

Project managers require significant effort[5] to forecast obvious and hidden risks associated with GSD factors, and perform necessary precautions to overcome challenges associated with these factors to succeed in GSD.[7] All these GSD factors affect project management activities and thus should be taken into account by project managers when estimating project schedule. Major Challenges in Global Software Development arise from geographical, temporal and cultural distances.[8]

The major consequent challenges are

i. Loss of Tameness
ii. Coordination and Control
iii. Loss of Communication Richness

1.3 Need for Coordination in GSD

(i) To manage interdependencies and achieve project goals when several actors are involved and multiple activities are performed

(ii) To suggest compatible process across sites to reduce distances and the amount of coordination required between client and vendor.

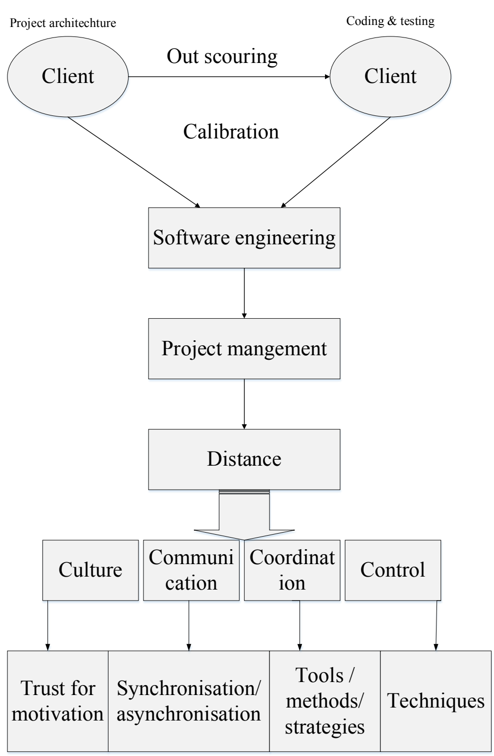

Fig. 1.1: Coordination between Distributed Teams in GSD Environment

GSD Issues

- Geographical Distance
- Temporal Distance
- Socio-cultural Distance
- Organizational Distance
- Technological Distance
- Knowledge Distance

1.3.1 Research Methodology

Interviews were chosen as the major research methodology. Depending on the communication between the partners, interviews can be divided into telephone interviews and personal interviews with both persons facing each other Telephone interviews have several advantages over personal interviews, mainly due to the ease of access: ever since the interviewer does not have to travel to the interviewee, the costs of telephone interviews are much lower. In addition, a large number of interviews can be conducted within a short amount of time. It is also easier to access interviewees who are reluctant to sacrifice time for a personal meeting. On the other hand, there are many disadvantages of telephone interviews compared to personal ones: Since only spoken words are transmitted over the telephone, it is harder to get information. This reduces both the possibility of the interviewer to formulate complex questions and his or her ability to obtain all of the interviewees' responses (e.g., their mimic action). The respondent might also not be willing to discuss sensitive topics over the telephone. Besides, the interviewer has less control compared to a personal interview. The interviewee can, for example, easily terminate the interview by simply hanging up the phone. Thus, it is recommended to use the telephone interview as an alternative only in certain circumstances. We tried to follow this guideline by conducting as many interviews as possible in person and only used telephone interviews if there was no other option. We also tried to minimize the problem by mailing the questionnaire to the interviewees in advance so that they had all questions in front of them. This helped very much to avoid misunderstandings during the interviews. Throughout the interview, we used a detailed questionnaire that contained both open and closed questions. All answers were recorded[9] and, with the exception of one, transcribed literally. The interview transcription and the notes were then analyzed using coding: Pieces of the answers were categorized and grouped together in order to identify commonalities and differences.

All interviewees confirmed that the six goals presented.

- Costs
- Time
- Quality
- Staffing
- Intellectual property protection
- Proximity to customer

Based on the outcomes of the interview study, several changes were applied to build a model which demonstrates the impact of GSD.

1.3.2 Problems in Communication, Coordination, and Control

The factors identified in the literature study as having an impact on communication problems were physical distance, language differences, cultural differences, differences in company culture, and common experiences of working together. Infrastructure distance, time shift and process maturity.[3] Out of these factors, time shift was mentioned most often as having the biggest impact on communication problems. Time shift between sites caused many problems because of delayed communication. The results are grounded in both a systematic literature review and a subsequent interview study; there is a set of threats to validity that have to be considered when interpreting the data.

- It was not possible to keep the factor deficiency of belief within the model because it was understood differently by the practitioners.
- Interviews were given to an outsider. This might have prevented the practitioners from reporting all problems openly.

The impact of all of the factors identified here does not only depend on whether a project is globally distributed or not, but also on the question of what the distribution of work across sites looks like: For example, the impact of task coupling and cultural differences on productivity is higher in a scenario in which closely coupled tasks are assigned to sites with large cultural differences compared to a scenario in which only tasks with loose coupling are assigned to different sites that have only low cultural differences between them.[4]

However, we discovered that in practice, work assignment is done rather unsystematically and takes into account only few factors, such as the availability of the workforce and local cost rates. This discrepancy between decision criteria and the fact that, at the same time, the practitioners reported many problems caused by the factors identified here indicates a potential for improvement.

We thus see a need for systematic decision support in GSD task allocation that can help practitioners to efficiently take into account all relevant influencing factors for their allocation decision and thus decrease the risks of global software development. In doing so, models like the one developed here are needed for understanding the impact of allocation decision on project success.

(A) Solutions to GSD Difficulties

Though many probable solutions are exists for every problems identified, but the organizations mainly focused on work standardization, planned assets, committed process and risk management for the solution. Evaristo suggested a solution that comprises integration and enhancement of trust between global teams. Carmel has supported effective requirements engineering and formal development process which focus on initial planning is mandatory for distributed project, assessing the project characteristics and the unit of work available for the project. furthermore, the process commitment plays an vital role to begin the communication between global teams. An additional solution applied was guiding in soft skills which projects mainly on nontechnical factors such as authority, communication, traditions, context involvement, project administration, and scientific training. When the global teams do not use the same process then standardization is appealed by considering three strategies such as driving standardization, merging practical components from different sites into novel methodology, and enforcing high-level guidelines. Risk management is drastically growing in both organizations. Some companies follow traditional risk management without taking the possible impacts of distribution, dissimilar cultures, schedule and attitudes. This has led to the necessity for global risk management process. Organizations are spending on the real requirements discovery which is essential for project characteristics and travel limitations. In every project major effort spend for the endorsement of project artifacts. At last, assimilation activities are conducted focusing mainly at trust achievement. Majority of these activities are achieved when teams meet & few of them are developed virtually.

(B) Global Software Development Critical Success Factors (CSF)

Based on organizational procedures Critical Success Factors are directly identified. For the similar activity it is possible to achieve different CSF related to the policies acquired by every organization. Summarizing the outcomes following critical success factors was identified. Formal software development process is considered to be significant factor for global projects. Variant CSF comprises huge allocation in training that evolved in enhanced relationships. The preliminary planning was vital for assessing global projects accurately and to choose the appropriate unit to allocate every project. Process commitment was measured as a success factor since it was the primary contact among global project teams. Combining activities enhanced soft skills of persons, improved beliefs and reducing the cultural differences among people. Finally, integration has enhanced the interaction and feedback.

1.4 Results

Even though the results are grounded in both a systematic literature review and *a* subsequent interview study, there is a set of threats to validity that have to be considered when interpreting the data.

- It was not possible to keep the factor "lack of trust" within the model because it was understood differently by the practitioners.
- Interviews were given to an outsider. This might have prevented the practitioners from reporting all problems openly.

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Innovative Surface Modification Techniques to Combat Corrosion

[1*]Deepak J, [2]Adarsha H, [3]Sunil Bhat, [4]Abhijeet Nagaraj

[1-4]Department of Mechanical Engineering, School of Engineering and Technology-JAIN (Deemed to be University), Kanakapura, Ramanagara, Karnataka, India.

*e-mail: deepakiyer31@gmail.com

ABSTRACT

Corrosion mitigation and prevention is one of the key areas of research in the present world scenario. Lot of damage is inflicted on the infrastructure due to corrosion. Since corrosion is a surface related mechanism, it can be controlled or even prevented by adequate surface modification technique. This chapter presents information about different innovative coating methods that are applied over substrates for reducing corrosion without altering the properties of the substrate. The benefits and limitations of the techniques are presented. Some notable studies conducted on various coating methods are also discussed.

Keywords: Corrosion, Surface engineering, Coating techniques.

1. Introduction

The economic development of any region, state or country, depends not only on its natural resources and productive activities but also upon the infrastructure that accounts for processing and marketing of goods. Irrigation systems, roads, bridges, airports, maritime, land and air transport, school buildings, offices and housing, industrial installations are all prone to corrosion and therefore susceptible to property deterioration and degradation with time. Corrosion is a worldwide crucial problem that strongly affects natural and industrial environments. Today, it is generally accepted that pollution and corrosion are interrelated harmful processes since many pollutants accelerate corrosion and form associated products such as rust that in turn pollute water bodies. Both are undesirable processes that impair the quality of the environment, the efficiency of the industry and the durability of the infrastructure assets. Corrosion of metals is reported to cost the U.S. economy almost $300 billion per year at current prices. Approximately one-third of these costs could be reduced by broader application of corrosion-resistant materials and practices. According to NASA, the cost of corrosion to the USA is around $276 billion per year. The total corrosion-related cost would reach $1 trillion by the end of the year. The NACE Corrosion Costs Study breaks up the US economy into 5 industries. The report outlines how much damage (in dollars) the corrosion does to each industry:

- Infrastructure: $22.6 billion
- Production and Manufacturing: $17.6 billion
- Transportation: $29.7 billion
- Government: $20.1 billion
- Utilities: $47.9 billion

Keeping the above in view, it is essential to develop and apply corrosion control methods. The appropriate selection of technique (e.g. coatings, inhibitors and cathodic protection) reduces the damage by corrosion and therefore cuts the costs involved. However, increased corrosion costs are at times also necessitated when higher and stringent performance requirements and more hostile environments are encountered.

Surface engineering, including surface treatments and coatings, is one of the most effective and flexible solution for reducing corrosion. Coatings change the surface tribological properties by inducing residual compressive stresses, decreasing the friction coefficient, increasing the surface hardness, altering the surface chemistry and changing the surface roughness.[1] They also improve the wear resistance of surfaces and thereby further extend the life of the components. During last several decades, numerous coatings and deposition methods have been successfully developed and tested to protect surfaces from damage. The increasing use of surface coatings in tribological applications is mainly based on the following reasons: - More and more scientists recognize that the surface is the most important part in many engineering components, and most failures have a relationship with the properties of the surface area. Many other functionally important properties depend on the surface such as electronic, magnetic, optical, bio-compatible characteristics. High quality performance required for mechanical components and tools cannot be realized just by selecting advanced materials. In this regard, the use of coatings becomes imperative to improve the performance of the surface regions while at the same time the substrate retaining its original properties responsible for the strength and toughness. In some special situations, the systems cannot function without advanced tribological coatings, for example, devices and bearing systems in space mechanisms operating under near-vacuum conditions or engineering components in aero-turbines running under corrosive or erosive conditions.

Advent of new coating technologies has promoted the possibility of depositing coatings with high efficiency that was previously unachievable. However, there are several problems associated with coatings as well. It is impossible to identify coatings with all the desired properties, such as high shear strength, high hardness, excellent bonding strength, high toughness, etc. because some of them are in conflict with each other. For example, fulfillment of high hardness calls for sacrifice in toughness and bonding strength. Therefore, we need to select the most suitable one from hundreds of thousands of coatings for a specific application, but how can we realize it? The use of coatings is a very complex system and there is no general rule to help the proper selection of a coating for a assigned tribological application.

2. Applications of Coatings

Selection of suitable coatings can decrease expenses and improve the product's efficiency as mentioned above. The application of coats that form the foundation for fresh products is offered by a broad range of alternatives. To obtain the required outcomes, it is vital to identify the fit-for-use coated system. Coatings find applications in the following industries[2]

- Oil and gas
- Aerospace
- Electronics and Sensors
- High temperature electronics
- Renewable energy generation
- Automotive
- Bio Medical applications
- Cutting tools
- Magnetic recording devices

3. Coating Techniques

Coatings are effectively used in various sections, from fundamental mechanical kinds to more stunning ones such as electronic gadgets. While the assembly of metallic coatings on surfaces is taken into account, thermal spray processes are widely used for mechanical applications.[3] Some leading methods for coating are described as follows:

Thermal Spray Coating

In this procedure, the feedstock is heated to a melting point and propelled into the working surface as individual drippings, typically in the form of powder or cabling, as shown in Figure 1. Fuel gasses or electrical arcs generate the energy needed for the melting process. They split (deform) and solidify, as particles impinge on the substratum. Due to the nature of this method, coatings typically show greater porosity, due to incomplete bonding of the sprayed material. Some of the advantages of this process include relatively low surface heating (350 to 450 °C) and high production rate. The elevated speed of deposition is 60-95% and thanks to its flexibility and simplicity which is commonly used in the sector.

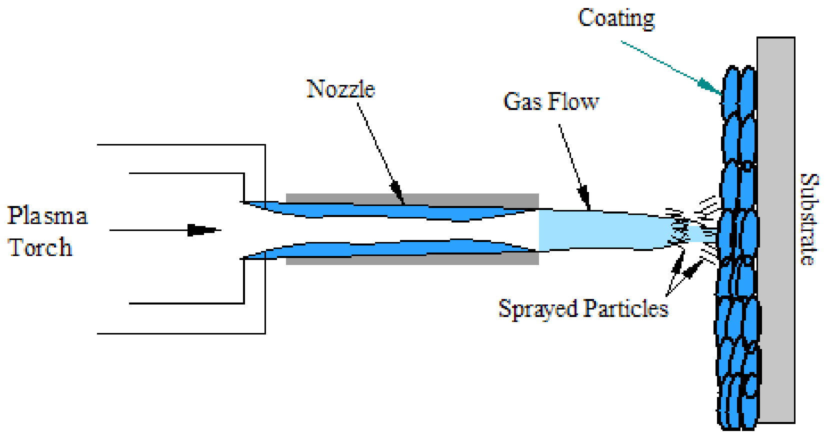

Fig. 1: Thermal spray process[4]

Low adhesion, elevated porosity and low heating effectiveness are some of the constraints. Materials with a melting point above 2800°C cannot be sprayed. The relative entering of ambient air oxygen with higher velocity can also cause the coatings to display elevated concentrations of oxidation. The high-speed oxygen fuel method (HVOF) is one of the version of conventional thermal spray where, it uses a high-pressure stream of gas. Here, the powder is injected and accelerated through the central line of the piston to be stored on the substrate and is generated by combustion of several kinds of fuel (kerosene, acetylene or propylene).

Cold Spray (CS) Method

In this process, feedstock powder is not melted but only accelerated at higher speeds via gasses that are supplied in a convergent-type nozzle at supersonic velocity. Usually nitrogen, air or helium is used for the purpose. The elevated kinetic energy of the particles causes serious plastic deformation and the development of a deposition layer on the particle impacts with the substratum. CS coatings usually demonstrate elevated bond strength, outstanding mechanical properties and powerful engineering interests over metals such as aluminium, titanium and alloys.

This technique has also been employed to deposit thermoplastic powder on non-metallic substrates. By using a laser source to add thermal energy to the deposition zone, Bray et al. (2009) have further enhanced the process, also enhanced binding force and promoted higher coating densities for low kinetic energy particles [5]. Cold Spray process is as shown in Figure 2.

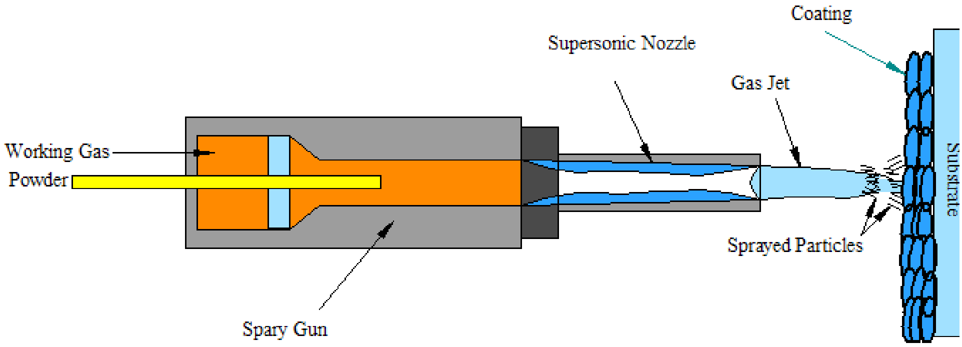

Fig. 2: Cold spray process[4]

Metallic coverings on surfaces such as plastics, textiles or composite materials are particularly interesting for engineering applications. It is particularly hard to deposit metals in the nature of such a substratum. Thermal spray technique through complete melting of the feedstock material has produced successful coatings.

Some of the benefits of cold spraying are that it uses low temperature and no melting of bulk particles. It eliminates stress on solidification and permits coatings that are thicker and small. Lower thermal input decreases the cooling demand and therefore no fuel gasses or extreme electrical heating are needed. This process is limited because hard brittle materials such as ceramics cannot be sprayed without ductile binding. It utilizes elevated flows of gas and therefore consumes big amounts of gas.

Plasma Spray Method

Plasma Spray Process is mainly the spraying on the surface of the material with another molten or heat softened material to provide the coating layer. Powdered material is injected into a plasma flames with elevated temperatures and is quickly heated and speeded up. The warm material affects the surface of the substrate and cools quickly to form a layer. This properly performed plasma spray method is called a cold process, as the substrate temperature during processing can be maintained at a low level, avoiding damage and metallurgy modifications and distortion. The set up is shown in Figure 3.

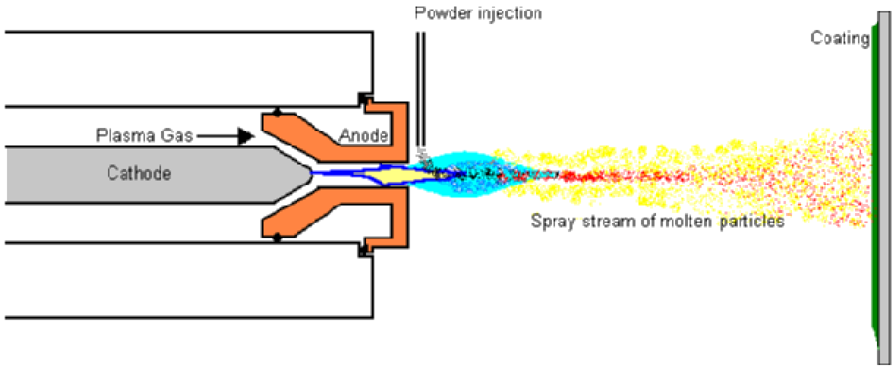

Fig. 3: Plasma spray method

In 2010 Jingxin Yang et al. worked on Magnesium (Mg) alloy plasma coating.[6] Plasma surface changes for biomedical use were examined in this study. They concluded that Mg and its alloys can be upgraded to a certain degree after modification of the surface by means of suitable plasma surface changes.

Usage of broad range of coating materials, with a broad range of distinct requirements, with almost all components accessible as appropriate powder, is some of the benefits of this procedure. Inflammation or electrical arcs are responsible for higher performance coatings. Various substratum types can be coated with the use of plasma spray. This can include metals, ceramics, plastics, glass and composite matter.

It has some constraints as well. The pumping equipment for air-plasma is usually very costly to purchase and use. It is an eye-catcher, comparable to all other thermal spray procedures, making it hard to cover tiny inner bores with limited diameters or access surfaces. The plasma pistol generally has the electrodes and other internal elements which get rapidly deteriorated. This often leads to weapon electrodes being replaced for quality control to preserve consistency of the layer.

Wire Arc Spraying Method

During this type of spraying method, two wires are fused with a short circuit arc and the fused materials are thinly sliced and sprinkled on the objects with compressed air. Spraying through electronic arcs and flame are commonly referred to as wire processes. For wire arc spraying material, all wired metals and alloys are accessible. Figure 4 illustrates the tool.

In 2012, Linlei Wang et al. worked on Iron (Fe) based amorphous/ nanocrystalline coated materials for AZ91 magnesium alloy substrates that were automatically sprayed at high speed arcs.[8] He found that Fe-based amorphous/

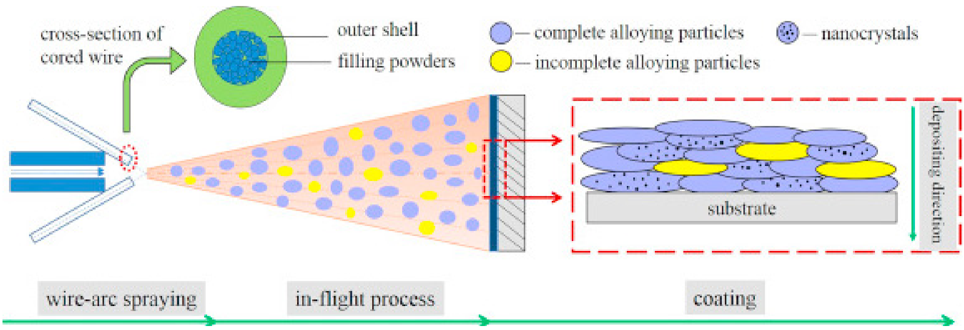

Fig. 4: Wire arc spraying[7]

nanocrystalline's resistance to wear is 2 times, 42 times, compared to 3Cr13, and the substrate shows excellent wear resistance, respectively.

Some of the benefits of this procedure include that the arc spray driving procedures with a deposition rate of 15 kg per hour or above have the largest deposition rate. The power input for plasma and HVOF spraying devices is extremely small at only 5-10 kW compared to 50 kW. Little training required for the operator. On the other side, the limits include big quantities of smoke and dust generated which leads to the operator wearing appropriate respiratory equipment and protective clothing. The quality of the covering does not generally match the results of plasma and HVOF spraying. The sprayed coatings usually have greater porosity and oxide levels and less bond strength compared to deposits of the coatings by plasma and HVOF spraying.

Physical Vapour Deposition (PVD)

The PVD technique as shown in Figure 5 is a group of procedures used for depositing thin layers of the materials, usually in the range of nanometres to several micrometers. PVD procedures are vacuum deposition methods which are eco friendly and consist of three basic steps.

Solid source material vaporization aided by vacuum or gaseous plasma at elevated temperature, convey vapour to the surface of the substrate in vacuum or partial vacuum and substrate condensation for generating thin films are the key steps adopted in this process. Although different PVD techniques use the same three basic steps, the techniques used for generating and depositing material are different. Thermal evaporation and sputtering are the two most prevalent PVD types. Thermal evaporation consists of a deposition method that uses suitable vacuum techniques to vaporize the source material by heating the material. Sputtering is a plasma-assisted process which produces a vapour by bombarding accelerated gaseous ions (usually Argon) out of the source target. The resulting stage of vapour is then deposited on the required surface via a condensation system both for evaporation and for sputtering.

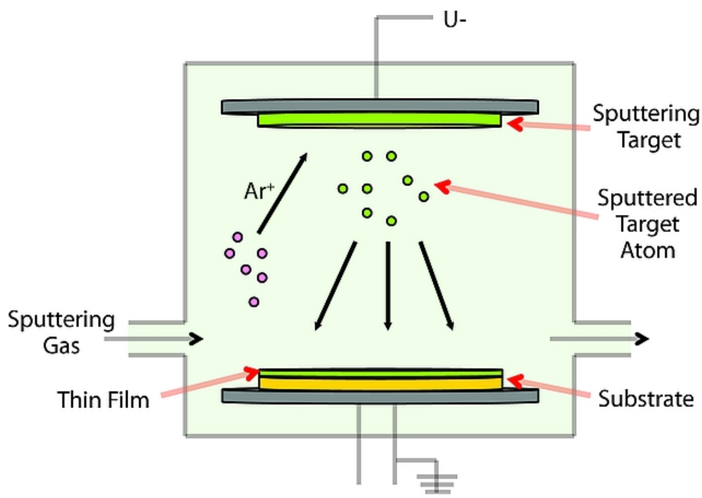

Fig. 5: Representation of physical vapour deposition

Some of the benefits are PVD coating is safer than other procedures as they involve comprehensive cleaning due to the use of chemicals and are not eco friendly. Also, almost every type of inorganic material can be coated with PVD. One inconvenience of PVD method is greater costs. The method needs complicated machines which require competent operators. The rate of operation of PVD coating is also comparatively slow and sluggish. PVD coating is still one of the best ways to improve the solidity and durability of a surface.

In 2007 magnesium alloy was studied by Hikmet Altun et al.[9] The research examined the impact of the coating on the wear behaviour of the alloy by coating the AlN/TiN with the magnesium alloys using the physical vapour deposition (PVD) technology of DC magnetron sputtering. The conclusion was that: AlN/TiN coating significantly enhanced the magnesium alloy wear resistance. For the AlN/TiN covering on the uncoated alloy, the surface hardness of the alloy improved about 70%. Although thick coatings were acquired, there were some typical flaws of the layer due to PVD techniques. Amorphous structure was present in the coating layer of AlN/TiN created on magnesium alloy AZ91.

Chemical Vapour Deposition (CVD)

CVD is a linear development procedure in which a precursor gas deposits a thin layer on a crust in a reactor. The growing method is small and the growth rate relative to thermal oxide is much greater. It also generates far finer layers of silicon dioxide because the film is placed instead of cultivated as shown in Figure 6. This method generates a film with a high electrical resistance, which among many other applications is suitable for use in IC and MEMS systems. When an external layer is required but silicon substrate may not be oxidized, chemical vapour deposition (CVD) oxide is carried out.

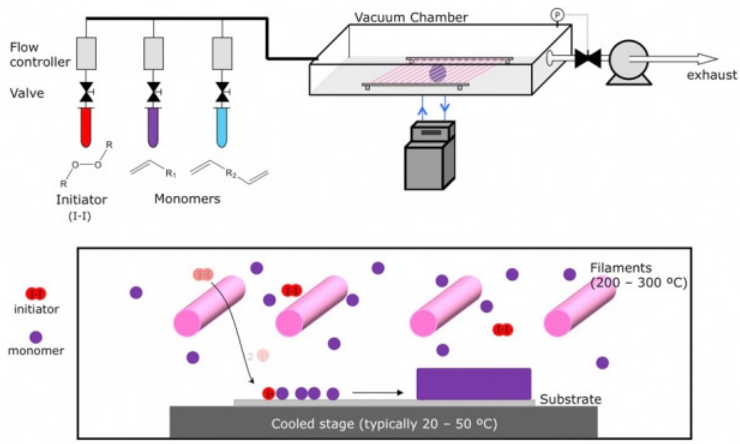

Fig. 6: Chemical vapour deposition

The 2019 work on magnesium alloys by Srinivasan Arthanari et al., protective performances have been examined on magnesium alloys for plasma-enhanced chemical vapour-deposited ethyl cyclohexane coating.[10] The Az31 and AM50 magnesium (Mg) alloys were placed with plasma-enhanced chemicals vapour deposition as plasma-polymerized ethyl cyclohexane (ECH). The effects of the moment of deposition on the forming, surface morphology, chemical structure and electrochemical corrosion behaviour have been examined.

As a method for depositing thin films, CVD has several merits. One of the key benefits is that CVD coatings mostly match the thickness of the film on side walls of components with the thickness on the top. The thickness is similar. This means that films can be linked to complex shaped parts and can be fully filled with high-aspect ratio and other characteristics. Another benefit of CVD is that they can be deposited with very high purity in relation to the broad array of products that can be deposited. It operates at fast deposition rates and CVD often requires no high vacuum, just like PVD procedures.

Moreover, CVD has several restrictions. The characteristics of the precursors are one of the main flaws. Precursors are unstable at room temperatures. Precursors also could be very poisonous, explosive, or corrosive. CVD responses can also result in damaging and dangerous outcomes. Some of these precursors can also be extremely exorbitant, especially metal-organic precursors. The other true weakness is the typical deposit of the films on greater temperatures.

Electrodeposition Method

Electro-deposition (ED) uses electricity to pull out the cations from a solution of the desired material and to filter this material on a leading substratum as a thin film. The principle functions on the electrolysis regulations of Faraday. The depository metal (anode) is both immersed in an electrochemical bath and the substratum (cathode) is transferred by the direct current. The bath may sometimes involve salt to be covered with metal. The anode serves only to complete the circuit in that case. The speed of corrosion may rely on the covered material. However, the duration of the coating process can be increased for increasing the thickness. Usually an electroplating layer consists of a single metal component. The process is shown in Figure 7.

This technique may be used in production of coatings containing organic nanofillers (for example, PEO, PTFE or inorganic or organic matrices). Many scientists have recorded the electrochemical coding of nano-composites for organic matrices.

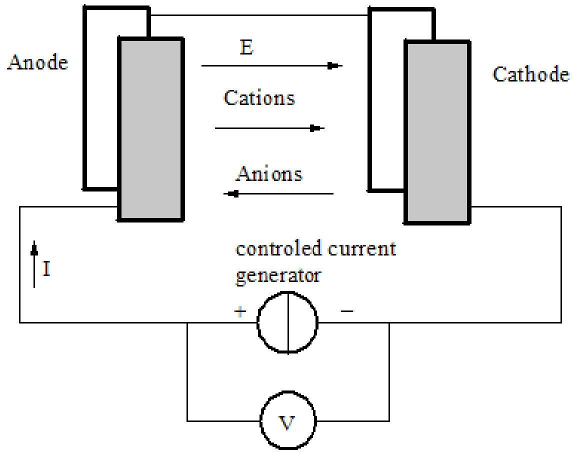

Fig. 7: Electrodeposition process[4]

Some of the strengths of electrodeposition are the strong potential trajectory to low-cost production. ED is a versatile deposition technique which can be used in the preparing of precursors layer structures to produce thin films from metals, metallically alloys and compounds. ED equipment is cheap and energy-efficient because it usually takes place near room temperature. When stable electrolytes with long lives are used, materials use in the electrodeposition process can be nearly

100 percent. Size and strength are the principal drawbacks of electro deposition. The electrical deposition is affected by an inferior factor of non-uniform thickness of the coating, i.e. the part of a substrate in the vicinity of the anode shows a higher thickness in comparison to that of the anode.

Solgel Method

The sol-gel process usually consists of the transformation from a liquid (mostly colloidal) "sol" structure into a strong "gel" stage. In the development of "sol," starting materials are generally inorganic metal salts or organic metal compounds, such as metal alcohoxides. The precursor undergoes a sequence of hydrolysis and polymerization responses during a typical sol-gel method to form a colloids suspension, or' sol.' Further "sol" processing allows materials to be produced in various shapes, such as monolith, movies, fibers and monocot powders. If after constant stirring the "Sol" is permitted to cool, a moist gel will be produced. Thin films of various characteristics can be placed on a substratum with spin-coating or dip-coating technique as shown in Figure 8. The "gel" is transformed into thick products with additional drying and heat treatment. Processes of sol-gel have demonstrated a range of benefits and drawbacks.[11]

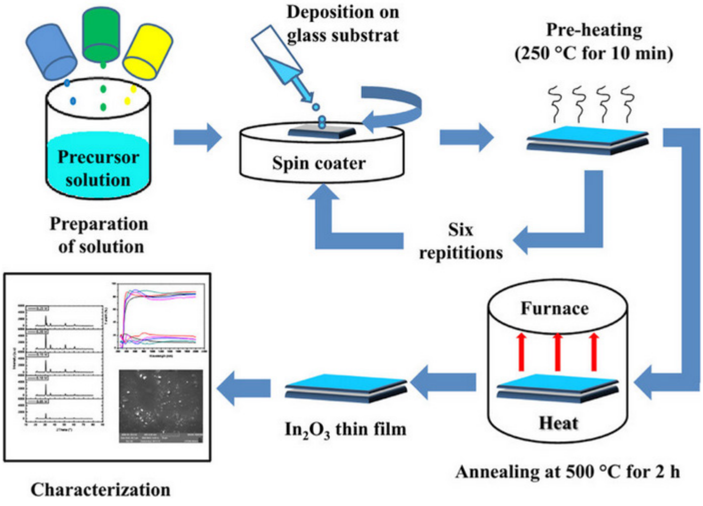

Fig. 8: Solgel process[12]

A main benefit of sol-gel coatings is simple and easy process, cost-effective, powerful adhesion and the barrier impact. Inorganic sol-gel coating delivers great barrier capabilities. This method can deposit a wide variety of products because of the chemistry engaged in the method. It comparatively uses small rinsing temperatures. Some of the constraints are prolonged processing times and low yield. It's not a very smooth method. Since the method includes a chemical response between several solution components, it includes in the necessary material unwanted electrons, molecules, ions, etc., which damages the electrical or optical characteristics of the deposited material. This method is therefore not consistent with the contemporary technology for the production of solid state equipment, which is the main method for electronic and photonic equipment.

4. Notable Studies

Yilmaz et.al. created composites of Nickel-Nano-TiO_2 using both pulse and direct coating methods.[13] Potential polarisation and electrochemical impedance spectroscopy techniques examined the corrosion efficiency of the coatings. The findings disclosed an outstanding corrosion-resistant Ni/TiO_2 composite, which was measured with a greater micro hardness.

Gawad et.al. have made and recorded microstructure, strength, and resistance to corrosions on the Ni-P Al_2O_3 and Ni-P–TiO_2 composite coating.[14] The potentiodynamic study indicate that the Cu corrosion current density has been decreased by over 95% protection efficiency by coating the copper substratum with Ni-P alloy which shows that the Ni-P deposits have a positive effect on the decrease in the corrosions rate in the active corrosion area.

By building super hydrophobic surfaces by the suspension flame spraying method Chen et.al investigated the efficiencies of Al coating.[15] A potential dynamic polarization analysis of the aqueous solution NaCl was carried out at room temperature at 3.5 wt%. The anti-corrosion results of super-hydrophobic coatings were measured. This layer probably prevents chloride ions (corrosive ions), which migrate and penetrate into the Al coating, thus increasing the anti-corrosion performance of the coating. A number of anti-corrosion applications could possibly be used with the new cost-effective superhydrophobic coatings.

The positive effects on mild metal substrates of wire-arc-sprayed steel coatings have been recorded for enhancing the behaviour of corroding by Zeng et. al.[16] The corrosive behaviour of the layer was followed by a cycling experiment of wetting and drying in a salt solution under the microscope. In relation to the non-sealing layer, the spray-treated coating was discovered to rust more quickly and secured the mild metal substratum from corrosion, but even the coating itself was deteriorated by the substratum interference as an anode. The air-atomized layer was rustier than the atomised nitrogen one.

Ahmed et. al. researched the connection between the electrical behaviour of HVOF thermally spray coatings of Inconel 625 on a forged sheet and its micro-structural properties.[17] The possible density of the passive current reduces when the porosity concentration has decreased. This suggests that at least portion of the corrosion improvements found by laser surface melting of coatings are due to porosity removal. The presence of porosity is suggested as the result of crevice corrosion in pores that improves the passive current density. Porosity removal eliminates this corrosion mechanism, thus enhancing the resistance to corrosion.

The impact of Ti interlayer on TiN PVD coatings corrosion resistance has been investigated by Vega et. al.[18] The testing of TiN-interlayer corrosion resistance was conducted using electrochemical techniques such as potentiodynamic polarisation tests, EIS and SECM. The findings showed that the corrosion resistance is improved with the use of dense Ti interlayer. An increase in propagation and a decreased diffusion coefficient can explain the enhancement. Increased TiN layer thickness increases the resistance to corrosion.

Huang et.al. researched on low-temperature CVD Graphene nanostructures on Cu and their corrosion properties.[19] The potentiodynamic polarization analysis on pure, CVD (C_2H_2, 5 min)-coated and CVD-coated Cu films were made. Experiments within the range of –0.8 V to 0.6 V v.s. were conducted. At the room temperature Ag/Agcl scan frequency was of 10 mV/s. originally, the potential of corrosion for pure Cu foil is about-0.267 V. The corrosion potential has moved to -0.2 V with several tens of mV and a comparatively small amount of corrosion after adding excellent CVD graphene layering. It shows that the property can be enhanced under adequate growth circumstances with the CVD graphene coating.

Tan et. al. investigated on the multi-layer magnesium sol-gel coatings.[20] The application of multilayer coatings resulted in corrosion safety of magnesium. Electrochemical tests show that the sol–gel layers provide corrosion protection through anodized pores and act as a barrier by physically sealing them. When the primary causes of degradation are defects and porosity, multi-layer application can eliminate the diffusion pathway for corrosive particles to reach the metal surface, thereby restricting localized attack occurrence.

5. Conclusion

Corrosion has a huge adverse impact on various aspects in heavy industry and in the society as well. As such, it has to be minimized for betterment of nation's economic development. Since corrosion is a surface phenomenon, it can be controlled by altering the properties of the surface. One among the methods to reduce corrosion is surface coating. There are various coating techniques that can be applied over different type of materials and the properties can be altered without affecting or damaging the substrate material. These coating techniques are presented and explained in this work. Notable studies conducted over application of different coating techniques are also discussed. The outcome of this study can lead to working on different material combination and coating techniques to create composites with reduced corrosion tendency in future.

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21

Development of Particulate Metal Matrix Composites

[1]Dr. N. Raghavendra, [2]Dr. D. Shivalingappa

[1]Associate Professor, Mechanical Engineering, BNM Institute of Technology, Bangalore
[2]Professor, Mechanical Engineering, BNM Institute of Technology, Bangalore
e-mail: ragu1676@gmail.com, dsivadvg@gmail.com

ABSTRACT

Composite Materials are potential materials for modern day application as compared to metals and alloys due to superior tailorable properties. Metal matrix composite (MMC) has better adaptability to extreme operating conditions as compared to polymer composites. The large scale developments with wide variety of matrix and reinforcements to obtain fairly good isotropic property is possible with Particulate metal matrix composites (PMMC). Although the Polymer composite development has been well established as compared to PMMC, more challenges are encountered in the development and commercialization of PMMC. In this chapter the aspects to be considered for the developments of PMMC are presented.

Keywords: Particulate, wettability, Interface, Strengthening Mechanism, Stir casting, MMC.

Introduction

Any materials used in application are intended to carry out specific function with desired properties. The pure metals and non-metals are incapable of possessing the required properties are significantly alloyed with organic and inorganic materials. The functional range of alloys are limited when the increase in demand for higher values of mechanical properties over wide range of operations becomes essential. The enhancement of the mechanical properties of the materials are significant as per the requirements due to the increase in capacity of machines and automobiles. But the alloys cannot have ability to meet the required specific properties due to limitations of the structural and material limits. The limitations of the alloys are eliminated by composite materials with the additions of oxides, carbides and borides to the matrix alloy. The advanced alloys are initially used for the military applications but gradually to increase the efficiency and to reduce the weight with the commercialization to introduce it to the automobile sector. The low cost of production and mass production concept of MMCs led to the development in automobile parts. Also with the increase in government norms and regulations towards the emission control, fuel efficiency has to be drastically increased only by reduction of vehicle weight, this can be achieved by use of light weight material in the production of parts. Traditional steel and cast iron is eliminated by introducing the Particulate MMCs. PMMC is the promising candidate to address the challenge.

Metal Matrix Composites (MMC)

Metal matrix composites are two phase mixtures containing an alloy as matrix and ceramics as reinforcements, both are physically and chemically distinct and insoluble in each other. Till 1970 the metal matrix composite are largely developed for military and aircraft applications but after 1970 more research funding in the area of research made MMCs as commercial product for all type of industrial use.[2] In 1980 research began in the development of discontinuously reinforced MMC, which opened the doors for further popularity of MMCs in the commercial application. Apart from mass production the properties are improved to greater extents as compared to unreinforced Alloys. The materials with highest strength are studied across all the countries but discontinuously reinforced materials are studied in academic research to larger extent. Due to these activities the application of MMCs has increased in wide range in the past three decade.[2] The application of MMCs include commercial vehicles, thermal management, aerospace, recreational, packing and infrastructure. The properties that make MMC more popular include wear resistance, thermal and electrical characteristics, structural strength, low density and fracture toughness. The challenges in the development of MMC to be taken care such as chemical compatibility, thermal miss-match, particle morphology, size, shape of reinforcements, secondary process, strengthening, wettability and interface reactions. The MMC industries are now matured industries, however extensions of manufacturing quantity, controlling parameter and applications for higher benefit for extension in breadth and length are still available for research.

Particulate Metal Matrix Composites (PMMC)

Particles of Ceramics can be added to the matrix for strengthening and load bearing purpose. This led to the development of Particulate composite in which the reinforcements are in the form of particles of few microns. The unique importance of Particulate MMC is strength and stiffness apart from this the particle distribution can be tailored to specific properties like wear resistance to aggressive environment, erosion resistance, high dimensional stability, impact strength and fracture toughness. The Particulate MMC provides improved affordability and suitability for mass production, three dimensional isotropy, suitability for secondary process and low density- light weight material system.[2] MMCs are utilizing large number of alloy system with many number of carbides, borides and oxides as reinforcements in large variety of shape and sizes.

The application of either continuous or discontinuous MMCs are in the areas of defense, aerospace, automobile and recreational.[3] The development of MMCs are advantageous but at the same time poses technological and policy barriers.

The Technological Barriers are:

1. Lack of commercial Application.
2. Lack of standard test procedure
3. Lack of analytical modelling techniques
4. Lack of industrial standards
5. Lack of nondestructive techniques
6. Problems like wettability, interface reactions, CTE mismatch
7. Lack of repair and recycle
8. Lack of Storage
9. Lack of Mass production facility
10. Lack of metallurgical understandings

The Policy barriers are:

1. Large capital investments
2. MMCs production and profit margin
3. Government policies and Technology path
4. Intellectual Property Right concern
5. Transmission & classification of Data
6. Environmental Regulations
7. Governments Recognition
8. Industrial Regulations
9. Reliability Index
10. Industrial Standards

Life cycle of MMC are spread over four stages:

The raw material for MMC are soft matrix material usually alloy and hard ceramic material usually carbides, borides and oxides. The Reinforcements are further continuous, discontinuous which are in the form of fiber, particulate, Whiskers or short fibers. MMC production stage includes development of MMC by various methods in which the reinforcement are uniformly distributed and wetted by the matrix. The process may be solid state process or liquid state process. The powder

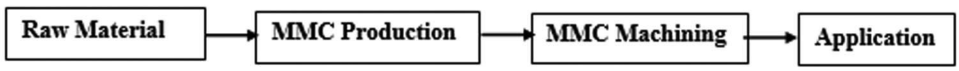

Fig. 1: Life cycle of composite material

metallurgy, spray deposition, stir casting process, melt infiltration, mechanical alloying are some of the popular methods for the production of PMMC. The secondary process like extrusion, rolling, solutionizing and ageing are used for optimization of MMC properties. The application part of discontinues MMCs for automobile part like diesel engine piston, bicycle frame, brake rotors, brake drum, engine liners, bearings, aircraft vertical stabilizers and continuous fiber reinforced MMC for structural applications parts like Hubble antenna boom, Space shuttle support struts, aircraft skins, turbine engine fan blades.[3] The various applications of continues and Discontinuous MMC are shown in figure 2.

Matrix and Reinforcement Materials

The matrix material used for the development of MMC is Aluminium, Titanium and Magnesium based alloys. The Titanium based alloys are used in high temperature applications and are limited to aircraft, missile and space shuttle applications. The Magnesium based alloy are used for structural applications but its usage is limited

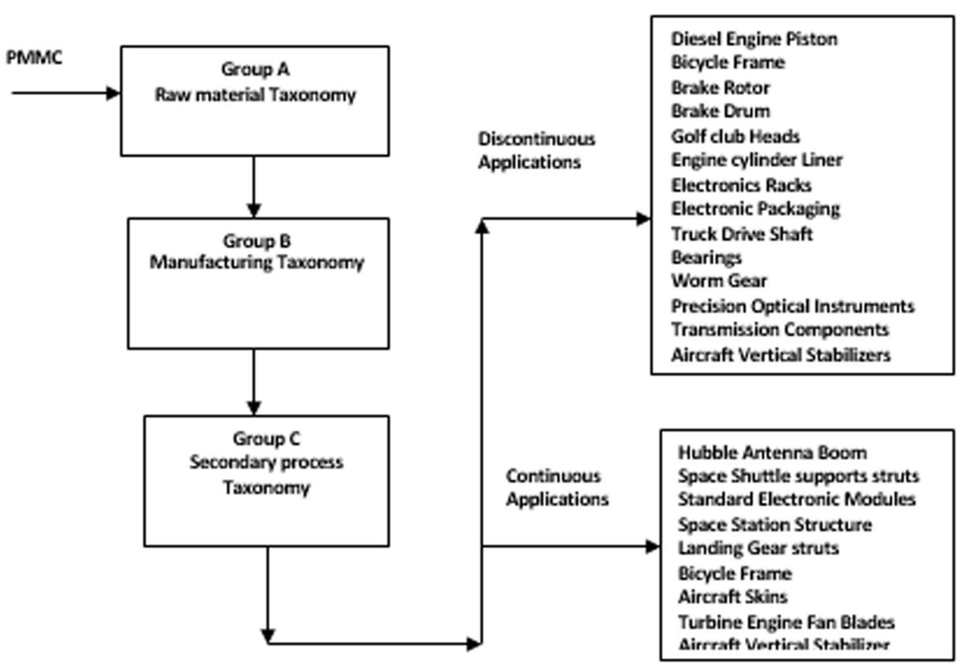

Fig. 2: Application of particulate and fiber composites[10]

due to low creep performance. The most popular alloy found in the development of MMC are Aluminium alloy. Material Selection for an application is based on characteristics of particular alloy.

Selection of Reinforcements

Seven mechanical and thermal properties are of direct interest in assessing the potential of a new composite: density, modulus, strength, toughness, thermal conductivity, expansion coefficient and heat capacity. Selection parameter considered for the matrix includes- Strength of the alloy, Availability of the alloy, compatibility with the reinforcement and heat treatable.

The reinforcement selection is parameter includes-Availability, Hardness, suitable for Tribological application, Stable with matrix material, high melting temperature, reinforcement size, shape, Density, Thermal expansion and reduced interface reaction during melting. Although the physical and mechanical properties may oftenlimit the constituent selection, it is the chemical reactivity of the reinforcement with the matrix alloy either during service or fabrication which will in most cases decides the final reinforcement/matrix combination. Particulate alignment is not a restrictive factor since such composites are generally designed for random orientations and any alignment is introduced as a result of the manufacturing process itself.

Wettability of Ceramic Materials

The reinforcement incorporation in to the matrix material without particle cluster and effective bonding between the matrix and reinforcements are the primary requirements of the composite material. It provides the strength and load transfer capacity to the matrix. The bond strength improves the hardness and fracture strength of the material. Weak strength in the bond results in failure to withstand the applied load and results in failure occurring at lower value. The particle incorporation in to the melt should overcome the particle pushing and agglomeration in the melt. The Knowledge of wetting of the reinforcement particle in the melt at various temperature conditions are to be studied before the development of the composite material to control the bond strength. The wetting of the reinforcement by the liquid melt is expressed in terms of contact angle between the solid and liquid phase. The contact angle desirable is less than 90° for the molten metal on the reinforcement surface. Generally it was found that most of the ceramics are non wettable at normal temperature. The formation of oxide on the metal surface and ceramic reduces the wettability. Under normal temperatures of casting MMC the temperature is generally lower and thicker oxide film on the surfaces causes fewer ceramic particles to be incorporated in to the matrix. The quantity of ceramics to be incorporated can be raised by using fluxes, gas shield or casting in vacuum. The inherent property of the ceramic cannot be eliminated completely to make ceramic entry in to the melt. The thermodynamic and mechanical limitations of the particle inclusion can be minimized by constant stirring or by pressure infiltration process. The metal is melted in controlled atmosphere or in vacuum to reduce the formation of oxide layer and to control the constant temperature to increase wettability.[5] The particle having oxide layer is difficult to be incorporated in to the melt which is mainly due to rejection of the particle by molten metal. The condition for incorporation of the particle in to the melt is shown in figure 3.The incorporation in terms of surface energy is given by $\gamma_{sv} > \gamma_{sl}$ where γ_{sv} is interfacial energy between particle and liquid, γ_{sl} interfacial energy between particle and gas.

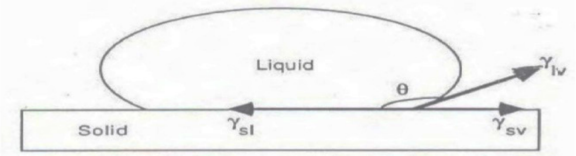

Fig. 3: Wettability of solid and liquid phases

The selection of reinforcement and matrix based on the surface energy and compatibility has to be considered for composite material with following points

1. Wettability of the ceramic particle by liquid matrix is primary requirements for selection. This can be carried out based on wetting angle data for the given ceramic at the temperature. If the wetting angle data are not available then flux based methods are used for the selection. The carbides, Borides and Oxides are wetted strongly as compared to ionic or covalent bonded materials. The reaction between the particle and he melt also facilitates wetting.
2. The particles should have close lattice match with the matrix. The particle which makes grain refinement in matrix will be ideal reinforcement for the MMC. If the lattice Structure are very close to each other than good incorporation can take place.[5] Both the mechanical barrier and the thermodynamic barrier are affecting the incorporation of ceramics in the matrix.

Interfacial Reactions in MMCs

The Particulate MMC containing the metal and the ceramic will be present as distinct phase with each other. The bond existing between the matrix and reinforcements depends upon the physical, chemical or mechanical phenomenon. The phase between the matrix and the reinforcement is termed as Interface or Interphase. The behavior of the MMC under the action of load can be established on the basis of Interface Bond strength. The desired strength, toughness, fracture strength, wear strength of a given MMC are strongly depends on interface bond strength. The chemical reaction between the reinforcement boundary and the matrix constitutes the interface product. The physical phenomenon controlling the interface are heat of formation, temperature, holding time, roughness of reinforcements, coefficient of thermal expansion, covalent bond and ionic bond etc. Rough surface of the ceramics improves the wettability, a large difference between coefficient of thermal expansion of matrix and reinforcements has to be avoided. Covalent bond is better than the ionic bond of the ceramics to avoid poor wettability. The chemical reactions at the interface will affect the strength of MMC. The molten metal are highly reactive with oxides and carbides. The chemical reactions will be oxidations of matrix and reductions of the reinforcements. These reactions at the interface causes chemical degradations of the ceramics leading to weak bond strength. The chemical reactions develops the different product that affects the performance.[6]

From the metallurgical point of view the solidification of the matrix has to be controlled to avoid the interface reactions. Due to difference in thermal conductivity of the matrix and reinforcement which induces localized thermal gradient. Insoluble impurities like Fe, Cu will be carried to the interface during solidification and results in formation of heterogeneities such as insoluble precipitates or enriched phases concentrated at the interface and grain boundaries when working with alloys (Cu-, Si containing Al alloys). This will reduce the bonding strength at the interface and ultimately the strength of composite. This can be reduced by process like solutionizing or heat treatment by dissolving in the al matrix. The interface phenomenon can be tuned in several ways in the MMCs to suit the reinforcement.

Solidification of MMCs

The work on research and development of Metal matrix Composite materials are existing from past 5 Decades, The mass production of the MMC are limited to certain applications. This has impacted the commercialization of the MMC Products. The factors affecting the mass productions are standard established process, low production cost, less complexity of production and defect free castings. Understanding the limitations of the other existing solid state process, challenges in the mass production has been established by casting route for the development. The research and development in industrialization of the MMC are gaining importance due to casting MMC in large quantity to reduce cost of production. Solidification of MMC during casting has been thoroughly researched to clearly establish the process parameters and final characteristics of the MMC for various combination of Matrix and Reinforcements. The solidification process is another phenomenon which has to be clearly understood to obtain the desired properties of the composite. The reinforcements in either particles, whiskers or short fibers are suitable for casting process utilizing in small or bulk quantities of reinforcements as compared to powder metallurgy.[7]

The casting process uses melting the matrix material in crucible at controlled temperature, addition of reinforcement and stirring at regulated speed. The mixture is further poured in to mould for solidification to produce the casting. The pouring and stirring actions are controlled which influences the solidification of the castings. The sand mould increases the solidification time which results in coarse grain size. On the other hand the metal mould reduces the solidification time to produce fine grain size. The parameters like engulfment, particle pushing and agglomeration are to be studied for sound castings. The solidification of the Particulate composites are influenced by solute segregation, heterogeneous nucleation, particle pushing, morphological instability, thermal shielding and agglomeration of the particles at the grain boundary. The variation in grain size, micro segregation, macro segregation and reinforcement distribution are noticed due to above factors. Controlled solidification parameters leads to the enhancement in mechanical properties and Tribological properties. The rate of solidification if controlled then it leads to better mechanical and Tribological properties. This is due to reduction in interface reaction, grain refinement, Precipitation formation, GP zone in the matrix, reduced porosity etc. The methods used for controlled solidification are Controlling processing parameters like holding temperature as low, Stirring time and speed as moderate, two stage melting process. The matrix and reinforcement selection based on the interface reactions, Secondary intermetallic in the base alloy, Reinforcements coating, Wettability etc. The detailed solidification control can be found in reference.[1,7]

The following phenomenon are studied in detail for the solidification of MMC-

Wettability - The wetting of solid surface of reinforcement by molten liquid in the casting process can be estimated by the pressure to be applied during the stirring process. The sold reinforcement has surface interaction with the melt. The wettability equations in terms of surface interactions are given by

$$\sigma_{SA} - \sigma_{SL} = \sigma_{LA} \cos\theta \qquad \ldots(1)$$

To improve the wetting of reinforcement σ_{SA} has to be increased or σ_{SL} had to be decreased.

The force induced over the particle will drag the particle in to the molten metal. The viscous drag is created due to stirring action which incorporates the particle in the matrix. When the molten metal are exposed to atmosphere the formation of the oxide layer on the surface reduces the penetration of the particles in to the melt. The particles when added to the melt tries to agglomerate due to reduction in penetration force acting. Due to these limitations of the particle incorporation various studies had developed the techniques such as 1. Reinforcement Pre Heating 2. Matrix Alloy Modification 3. Coating the Reinforcements.

Heat treatment of the reinforcement before adding to the melt improves the particle incorporation. In this process the gaseous surfaces are treated and σ_{SA} is raised. Adding Lithium or Magnesium can improve the wetting of the reinforcements and incorporation. The coating provided on the reinforcements reduces the Oxide layer formed due to oxidation and improves the wettability.

In physical bond the reaction between the matrix and reinforcements are absent and the attractive force between the matrix and reinforcement are binding the two. Aqueous solvents, organic solvents and polymers are containing physical bond at the interface. Also the shrinkage of the matrix material during solidification binds the reinforcements by physical bond. In the chemical bond due to reaction between the matrix and reinforcements which produces work of adhesion provides the bond strength. This strength is higher order and more than the physical bond. Transportation Phenomenon is the final process in solidification which takes place due to advancing metal containing the dispersed particles. The Matrix in the liquid state converts in to solid state during solidification starting from the mould walls. The melt contains the dispersed particles which are forced by the advancing solid front. Three possibilities are found during this process 1. Solidifying front pushing the particle slowly, 2. Engulfment of the Particles by advancing solidified metals, 3. Entrapment of the particle in the regions of inter dendritic passage as shown in figure 4.

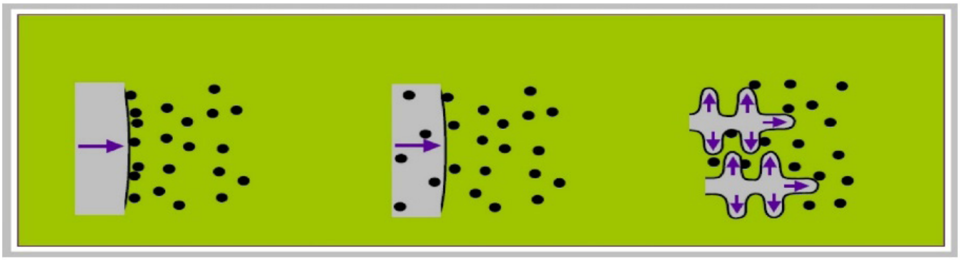

Fig. 4: Transportation phenomenon in solidification process

the distribution of the reinforcement in the melt depends on

1. Quality of the particle slurry prior to casting
2. Cooling rate
3. Viscosity of solidifying melt
4. Shape, size and volume fraction of the Particle
5. Specific gravity of the melt and Particle
6. Thermal properties of matrix and reinforcements
7. Chemistry and morphology of crystallizing phases and interaction with Particles
8. Entrapment or pushing of the particle by solidifying interfaces.[8]

The boundary separating the reinforcement and matrix are referred as interfaces. The property of the composite material largely decided by the nature of the interface. Strong interface increases the tensile strength and young's modulus of the composite materials. Interface depends on Nature of the reinforcement surface, Fabrication techniques and chemical reactions of matrix and reinforcements.[9] The physical properties, chemical bonding and mechanical performance are the profound parameter in the design of MMC. The studies of interfacial phenomenon are mainly based on the two categories of manufacturing route 1. Solid state process, 2. Liquid state process. The solidification or sintering of the matrix and reinforcement takes at high temperature in which two types of interactions occurs during cooling. In the first case chemical interaction develops the chemical bond and the physical interaction develops mechanical bond. The wettability, surface energy interactions are physical phenomenon and chemical reactions between the phases occurs due to chemical affinity. The physical phenomenon wettability to be improved in the solidification process and low affinity for chemical reaction to be established which reduces the degradation of the ceramic and matrix interface. Only selection of matrix and reinforcement will not satisfy these conditions and suitable process of treating the reinforcement with coating and pre heating are usually adopted.[9] The physical phenomenon wettability depends on the heat of formation, atomic structure, molten metal, temperature, time of interaction, atmospheric condition, crystal structure and roughness. Irregular surface of the reinforcements will interlock with the solidification front with good bond strength but induces the residual stress which can be relieved by heat treatment. Large gap in thermal expansion coefficient of the matrix and reinforcements gives rise to weak bond resulting in failure at higher forces. The chemical phenomenon at the interface are thermodynamic reactions based on the enthalpy of molten metal and reinforcement composition. The oxidation and reduction on either side of matrix and reinforcement gives rise to formation of unwanted layer reducing the bond strength between two phases. The temperature control of solidification and interaction time influences the oxide formation in the interface regions. The interfacial reactions leads to the generation of new phases at the interface due to reactions between matrix and reinforcement and starts depositing on the reinforcement surface leading to poor strength. The reactions products deposited at the interface is brittle in nature which reduces the bond strength and degradation of the mechanical properties at the interface.[6]

Strengthening Mechanisms

Strengthening mechanism of MMC are classified as direct strengthening and indirect strengthening.[8] The characteristics approach of composite material can be predicted by continuum approach and micro-mechanics approach. The strengthening mechanism of composite in first approach uses global parameters and the later uses deformation at atomic level. Strengthening mechanisms are generally derived by micro mechanist approach. All the strengthening mechanisms are initially derived for various alloy but same phenomenon can be extended to Particulate composite also.[19] The work carried by some researchers like Miller and Humphreys are significant for strengthening mechanism. The mechanisms are 1. Quench strengthening 2. Grain strengthening. In the first method solid solution was treated so that dislocation are created by difference in thermal expansion coefficient between the matrix and reinforcement. The quantity of dislocation created depends on the reinforcement size, shape and volume fraction.

The strength was given by

$$\boldsymbol{\sigma d = \alpha\, G\, b\, \rho^{1/2}} \qquad \ldots(2)$$

Where, σd = strength, α = constant between 0.5 and 1, G = modulus of shear, b = Berger's vector ρ = dislocation density

$$\boldsymbol{\rho = 12\Delta T\, \Delta C\, Fv/bd} \qquad \ldots(3)$$

Where ΔT = temperature change, ΔC = Product of thermal miss-match, Fv = reinforcement volume fraction, d = reinforcement size

The uniform distribution of the reinforcement leads to uniform increase in strength in the composite. The second approach by grain strengthening, the grain refiners are used which will generate fine grain size than the unreinforced alloy imparting more strength. The strength is related to grain size by Hall-Patch equation

$$\boldsymbol{\sigma_o = \sigma_I + K\, D^{-1/2}} \qquad \ldots(4)$$

σ_o = yield strength, σ_I = fraction stress representing over all resistance of the lattice to dislocation moment D = grain Diameter.

The strengthening mechanism are also developed in MMC by secondary process and work hardening. The process like Rolling. Extrusion, Age hardening, Strain hardening develops greater strength due to grain refinement and reduction of porosity.

Processing of Particulate Metal Matrix Composites

The procedure employed for combining the reinforcement and matrix are numerous. The ultimate goal of each of the process is to have a good distribution of dispersoid and elevated mechanical properties. Specific process are designed according to required property enhancement. All the process used for the production of MMC are controlled by metallurgical phenomenon. The thermal energy, mechanical energy and the chemical reactions are exploited during the process of manufacturing. The fundamental understanding of compatibility of matrix and reinforcements are essential in terms of Parameters as following

1. Wettability
2. Interface reactions
3. Thermal Expansion
4. Reinforcement distribution
5. Temperature effects
6. Grain size and grain boundary size
7. Orientation, size, volume fraction of reinforcement

These has to be studied before the selection of production process. Also the behavior of material system before and after the process is to be studied. The fabrication of the MMC includes primary process and secondary process. The primary process involves the fabrication of the composite from matrix and reinforcements and the secondary process involves the processing of the fabricated composite by rolling, forging, extrusion, heat treatment etc. The secondary process produces wrought products.

The primary process is classified as solid state process and liquid process.

Solid State Processing

1. Powder Metallurgy Process
2. Powder Extrusion
3. Accumulative Roll Bonding
4. Diffusion Bonding
5. Explosive Shock Consolidation

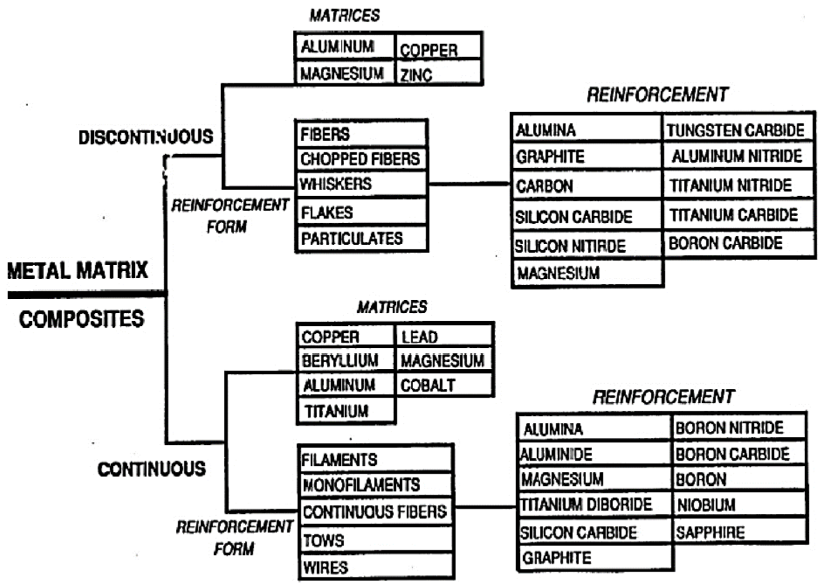

Fig. 5: Matrix and reinforcement for continuous and discontinuous MMC[11]

Liquid State Processing

1. Stir Casting
2. Liquid Infiltrating
3. Squeeze casting
4. Spray co deposition
5. In situ Process

Classification of the Solid State and Liquid State process and secondary process are shown in figure 6.

Solid State Processing

The solid state process involves blending the matrix and reinforcement powder followed by compaction. Thermal treatment of compacted materials are carried out as per the requirements. The uniform distribution of the particles can be achieved to a greater extent in solid state processing. But for the compaction large amount of forces are applied which leads to the fracture of the particles or fibers. The material handling systems are complex and involves high cost of production. Processing of particulate Composite by solid state process (Powder metallurgy) includes matrix and reinforcements used in the form of powder, followed by blending and sintering. Homogeneous distribution can be achieved by blending with controlled parameters and through mixing of the powders. The ratio of size of the reinforcements to matrix particles is important factor for uniform distribution. It produces defect free composite due to low temperature and compaction.

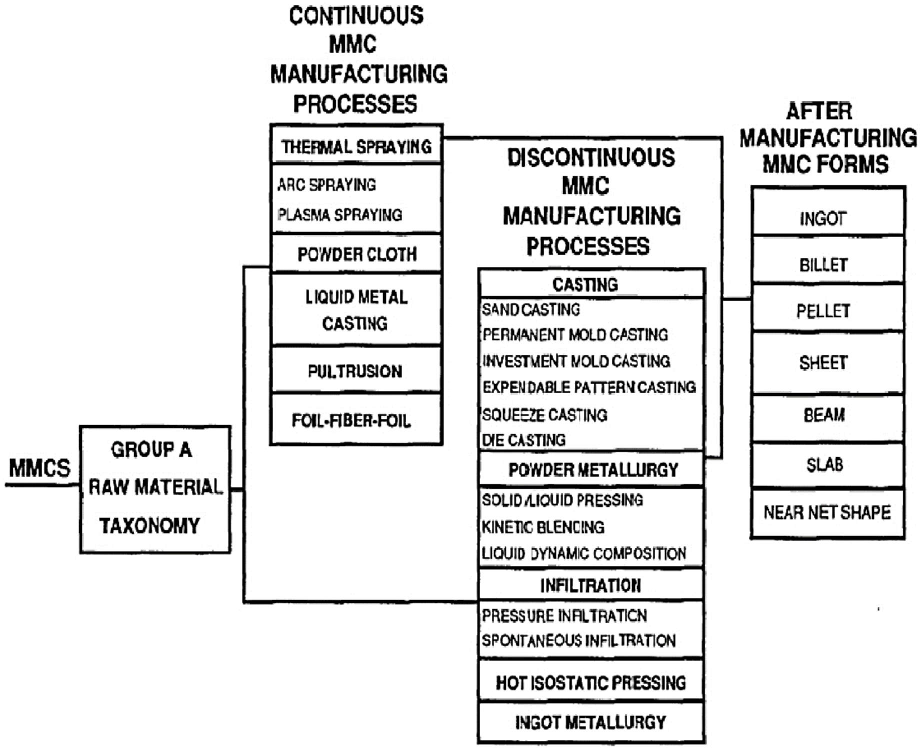

Fig. 6: Primary and secondary Process for MMC[11]

Liquid State Process

It is the primary process in the development of discontinuous reinforcements by melting the matrix material and adding the pretreated ceramic powder with proper mixing. The liquid state process employed for the development of Particulate MMC is a low cost, suitable for mass production and sound castings are produced. It is one of the more widely used processes for Particulate MMC. It is having simple production methods and suitable for wide variety of reinforcements size, shape and volume fractions. Due to difference in the density of molten metal and the reinforcement the following techniques are employed for the development of MMCs by various methods:

1. Melting matrix material and addition of reinforcement powder in to the molten metal at regulated temperature

2. Addition of particles with the help of carrier gas (inert gas injection jet)
3. Aluminium foil covered reinforcements are added in a small quantity in to the melt with stirring.
4. Addition of reinforcements in to the vortex created in the melt
5. Distribution of powder in the melt by rotating the mold to create centrifugal force
6. Mechanically pushing the particles by push rods in to the melt
7. Using ultra sound to inject the particles
8. Vacuum injection of the particles and stirring.[11]

Discontinuous MMC are First composites to be commercialized and the details of advantages of the Discontinuous MMC (Particulate MMC) are as shown in the Table 1.

Table 1: Particulate metal matrix composites summary[11]

Discontinuous MMC				
MMC Process	***Matrix Form***	***Reinforcement Form***	***Process Advantage***	***Company Using***
Melt Oxidation	Liquid	Pre form	Able to form complex shapes	Lanxide
Ingot Metallurgy	Liquid	Powder	Lowest cost to manufacturer, Good for high volume and high stiffness and wear resistance applications.	Duralcan
Powder Metallurgy	Powder	Powder	Good strength and stiffness properties, near net shape forming	ACMC, DWA
Cospray	Liquid droplets	Powder	Uniform particulate distribution and more economical than PM	Alcan
Rapid Solidification	Flakes	Flakes	Better strengthening of composite and low temperature processing so no degradation of properties.	Pacific Northwest Laboratories.

Conclusion

Particulate Metal Matrix Composite are of research interest from last three decades in relation to applications in automobile and aircraft parts. The limitations of performance of the alloy in spite of additional secondary process, heat treatment and strengthening mechanisms has led to the search of new material system. The limitations of fiber composite in terms of unidirectional properties and cost are overcome by use of particulate composites. The Particulate based composite material system are considered as replacement to polymer composites. The challenges of development of Particulate composite in terms of matrix, reinforcement selection, compatibility, interface reaction, wetability, solidification process parameters and type of fabrication process has to be considered. The major advantage of Particulate MMC are low cost of materials, Chemical Compatibility suitable for mass production and possesses isotropic properties.

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Web Mining

[1]N. Vani, [2]Dr. T.M. Veeragangadhara Swamy

[1]Assistant Professor, Department of Computer Science and Engineering, Rao Bahadur Y. Mahabaleswarappa Engineering College, Bellary-583104

[2]Professor, Department of Computer Science and Engineering, Rao Bahadur Y. Mahabaleswarappa Engineering College, Bellary-583104

e-mail:vanimtech.z@gmail.com, Swamytm@gmail.com

I. Introduction

Today internet is faster changing technology with rapid growth and increasing demands of users day by day. To extract information from huge documents of web as per user requirements at a faster rate is most challenging task. Web mining is useful to get data in faster rate as per user specific interest. it reduces time of server and cost saving and increases speed of response and improves performance of server system. Web mining gets information which is useful and finds knowledge from user click streams, hyperlinks and behavior of user. There are 3 categories in web mining such as web structure mining, web content mining and web usage mining. The web structure mining gets structure of data been accessed by user. The web content mining gets information about type of content being extracted by user. The web usage mining records every click made by user and identifies patterns from log files. The main objective of web usage mining is used to identify user interest and predicts user navigation.

Web Mining is the extraction of interesting and potentially useful patterns and implicit information from artifacts or activity related to the World Wide Web. Web usage mining provides the support for the web site design, providing personalization server and other business making decision, etc. In order to better serve for the users, web mining applies the data mining, the artificial intelligence and the chart technology and so on to the web data and traces users' visiting characteristics, and then extracts the users' using pattern. It has quickly become one of the most important areas in Computer and Information Sciences because of its direct applications in e-commerce, CRM, Web analytics, information retrieval and filtering, and Web information systems.

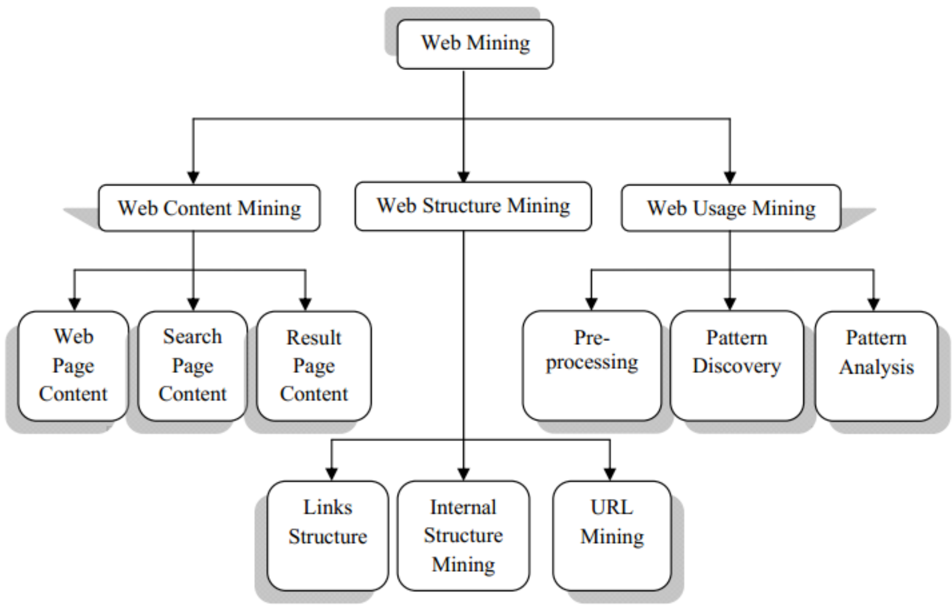

Fig. 1: Web mining taxonomy

There are three types of web mining:

1. Web content mining
2. Web structure mining
3. Web usage mining

1. Web Content Mining

Web content mining is the process of extracting useful information from the contents of web documents. Content data is the collection of facts a web page is designed to contain. It may consist of text, images, audio, video, or structured records such as lists and tables.

Application of text mining to web content has been the most widely researched are following:

- **Topic Discovery and Tracking,**
- **Extracting Association Patterns,**
- **Clustering of Web Documents,**
- **Classification of Web Pages.**

Research activities on this topic have drawn heavily on techniques developed in other disciplines such as

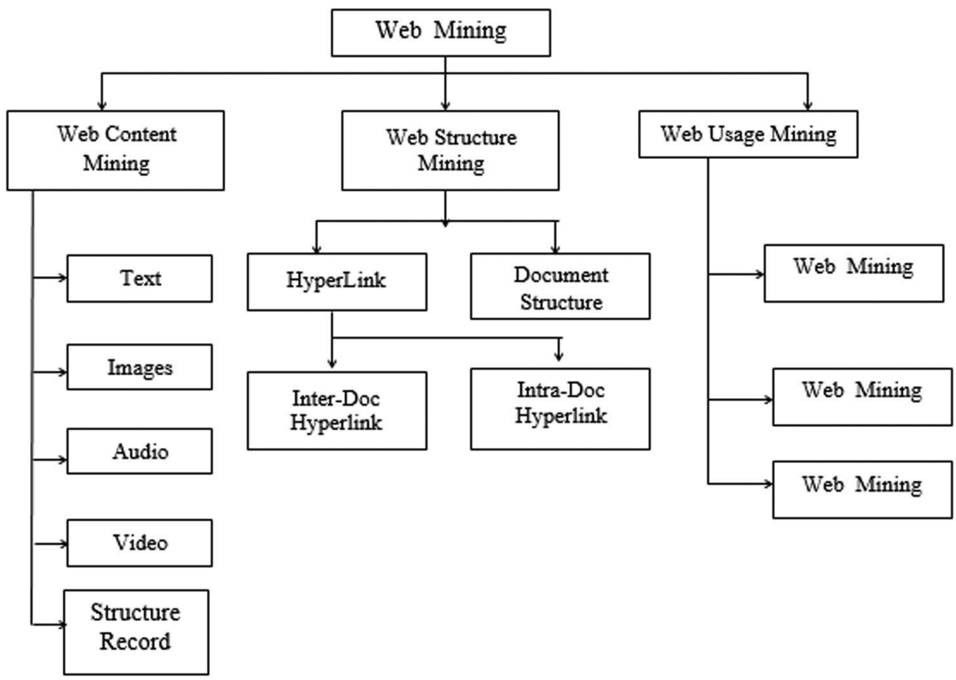

Fig. 2: Web mining types

- **Information Retrieval (IR) and**
- **Natural Language Processing (NLP).**

2. Web Structure Mining

The structure of a typical web graph consists of web pages as nodes, and hyperlinks as edges connecting related pages. Web structure mining is the process of discovering structure information from the web. This can be further divided into two kinds based on the kind of structure information used.

- **Hyperlinks:** A hyperlink is a structural unit that connects a location in a web page to a different location, either within the same web page or on a different web page.
  - **Intra-document hyperlink:** A hyperlink that connects to a different part of the same page is called an intra-document hyperlink.
  - **Inter-document hyperlink:** A hyperlink that connects two different pages is called an inter-document hyperlink.
- **Document Structure:** The content within a Web page can also be organized in a tree structured format, based on the various HTML and XML tags within the page.

3. Web Usage Mining

Web usage mining is the application of data mining techniques to discover interesting usage patterns from web usage data, in order to understand and better serve the needs of web-based applications. Usage data captures the identity or origin of web users along with their browsing behavior at a web site. web usage mining itself can be classified further depending on the kind of usage data considered:

- **Web Server Data:** User logs are collected by the web server and typically include IP address, page reference and access time.
- **Application Server Data:** Commercial application servers such as
  - **Weblogic**
  - **StoryServer**

  The significant features are to enable E-commerce applications such as B2B E-commerce and B2C E-commerce. A key feature is the ability to track various kinds of business events and log them in application server logs.
- **Application Level Data:** New kinds of events can be defined in an application, and logging can be turned on for them for generating histories of these events.

II. Real Time Applications

The web applications being developed at a much faster rate in the industry than research in web related technologies. Many of these are based on the use of web mining concepts, even though the organizations that developed these applications, and invented the corresponding technologies.

1. Web Search—Google

Google is one of the most popular and widely used search engines. It provides users access to information from over 2 billion web pages that it has indexed on its server. The quality and quickness of the search facility makes it the most successful search engine. Earlier search engines concentrated on web content alone to return the relevant pages to a query.

Google was the first to introduce the importance of the link structure in mining information from the web. PageRank, which measures the importance of a page, is the underlying technology in all Google search products, and uses structural information of the web graph to return high quality results. The Google toolbar is another service provided by Google that seeks to make search easier and informative by providing additional features such as highlighting the query words on the returned web pages. The full version of the toolbar, if installed, also sends the click-stream information of the user to Google. The usage statistics thus obtained are used by Google to enhance the quality of its results. Google also provides advanced search capabilities to search images and find pages that have been updated within a specific date range. Built on top of Netscape's Open Directory project, Google's web directory provides a fast and easy way to search within a certain topic or related topics. The advertising program introduced by Google targets users by providing advertisements that are relevant to a search query. This does not bother users with irrelevant ads and has increased the clicks for the advertising companies.

2. Web-Wide Tracking—DoubleClick

Web-wide tracking is tracking an individual across all sites he visits, is an intriguing and controversial technology. It can provide an understanding of an individual's lifestyle and habits to a level that is unprecedented, which is clearly of tremendous interest to marketers. A successful example of this is DoubleClick Inc.'s DART ad management technology.

DoubleClick serves advertisements, which can be targeted on demographic or behavioral attributes, to the end-user on behalf of the client, i.e. the web site using DoubleClick's service. Sites that use DoubleClick's service are part of The DoubleClick Network and the browsing behavior of a user can be tracked across all sites in the network, using a cookie. This makes DoubleClick's ad targeting to be based on very sophisticated criteria.

3. Understanding Web Communities—AOL

One of the biggest successes of America Online (AOL) has been its sizeable and loyal customer base. AOL provides them with useful information and services. Over time these communities have grown to be well-visited waterholes for AOL users with shared interests. Applying web mining to the data collected from community interactions provides AOL with a very good understanding of its communities, which it has used for targeted marketing through advertisements and e-mail solicitation. In return, consumer survey and new product development experts of the sponsoring organization get to participate in the community, perhaps without the knowledge of other participants. The idea is to treat the community as a highly specialized focus group, understand its needs and opinions on new and existing products, and also test strategies for influencing opinions.

4. Understanding Auction Behavior—eBay

eBay started as an online auction house in the 90s for people to sell collectibles and used goods to one another. Today, 80% of items sold on the platform are new, and 89% of items are sold at a fixed price.

eBay is taking steps to make its platform look and operate more like Amazon. It's encouraging sellers to offer free guaranteed 3-day shipping. It's combining product listings from sellers with the same item, enabling consumers to find the best price more easily. It also launched a Best Price Guarantee, offering customers a 110% rebate on the difference between an item they bought on eBay and an identical listing on a competitors' website. eBay is operating more and more like a business-to-consumer retailer instead of a marketplace for other businesses.

The moves are starting to pay off. GMV growth (on a currency-neutral basis) started accelerating in 2018, growing 7% in the first half of the year. Still, that growth is considerably slower than other companies on this list, and slower than the overall growth of the e-commerce industry.

While eBay turns around its GMV growth, it's also working to increase its profit margin. It moved to intermediate payments itself by starting to cut ties with former subsidiary **PayPal**. The company will handle all of its payments in-house by 2021, which the company expects to provide significant value to sellers on the platform. That could result in both higher profits and better GMV growth.

In September 1995 eBay opened the first Internet based consumer to consumer auction. The corporate model was to provide a central market for the sale of goods. Independent sellers use eBay to sell their goods through auctions lasting from three to ten days so that bidders can bid at a convenient time. eBay's revenues are primarily from the posting and sales of goods. They extract two primary fees, a listing fee and a sales fee. These fees are increasing in the reservation price the auctioneer sets and the final sales price, with a maximum of 5 percent of the final sales price and listing fees under two dollars. The mean listing fee was one dollar for the monitors in our data set, and final sale fee was $2.50, with a median final sales fee of $1.50. For all of eBay at the time our data was collected the average fee per item auctioned–not all of which sell–was $1.41, and 7 cents in fees were generated for every dollar of sales.

5. Personalized Customer Experience in B2C E-commerce—Amazon.com

Amazon.com crafted a new business model in the 1990s for Internet entrepreneurs using the Web as a place for transactions. As consumers learned to replace physical distance with mouse clicks, Amazon created e-business and e-commerce models that generated massive profits for the online clearinghouse.

Amazon helps a seller create her own page on which she can list her products, that's serving consumers, too, although not directly. However, Amazon also offers its own products, both new and used, which consumers can purchase directly from Amazon. Now that Amazon has entered the digital media realm with its exclusive Kindle e-reader and selection of e-books, Amazon serves consumers in this way, too. Through the Amazon Prime service, Amazon provides consumers with discounted instant video and e-books as well as free shipping specials for a monthly fee.

The main effort is in getting a customer to the store. Once a customer is in the store they are likely to make a purchase — since the cost of going to another store is high — and thus the marketing budget is in general much higher than the in store customer experience budget (which keeps the customer in the store). In the case of an on-line store, getting in or out requires exactly one click, and thus the main focus must be on customer experience in the store.

When Amazon helps a seller create her own page on which she can list her products, that's serving consumers, too, although not directly. However, Amazon also offers its own products, both new and used, which consumers can purchase directly from Amazon. Now that Amazon has entered the digital media realm with its exclusive Kindle e-reader and selection of e-books, Amazon serves consumers in this way, too. Through the Amazon Prime service, Amazon provides consumers with discounted instant video and e-books as well as free shipping specials for a monthly fee.

6. Personalized Portal for the Web—MyYahoo

Yahoo was the first to introduce the concept of a "personalized portal," i.e. a web site designed to have the look-and-feel and content personalized to the needs of an individual end-user. This has been an extremely popular concept and has led to the creation of other personalized portals such as Yodlee for private information like bank and brokerage accounts. Mining MyYahoo usage logs provides Yahoo valuable insight into an individual's web usage habits, enabling Yahoo to provide personalized content, which in turn has led to the tremendous popularity of the Yahoo web site.

7. CiteSeer—Digital Library and Autonomous Citation Indexing

CiteSeer works by crawling the web and downloading research related papers. Information about citations and the related context is stored for each of these documents. The entire text and information about the document is stored in different formats. Information about documents that are similar at a sentence level (percentage of sentences that match between the documents), at a text level or related due to cocitation is also given. Citation statistics for documents are computed that enable the user to look at the most cited or popular documents in the related field. They also a maintain a directory for computer science related papers, to make search based on categories easier. These documents are ordered by the number of citations.

8. Google Analytics

Google Analytics is a web analytics service offered by Google that tracks and reports website traffic, currently as a platform inside the Google Marketing Platform brand. Google launched the service in November 2005 after acquiring developer Urchin.

Fig. 3: Google analytics

Google Analytics is the most widely used web analytics service on the web. Google analytics is used to track the website activity of the users such as session duration, pages per session, bounce rate etc. along with the information on the source of the traffic. It can be integrated with Google Ads, with which users can review online campaigns by tracking landing page quality and conversions (goals). Goals might include sales, lead generation, viewing a specific page, or downloading a particular file. Google Analytics› approach is to show high-level, dashboard-type data for the casual user, and more in-depth data further into the report set. Google Analytics analysis can identify poorly performing pages with techniques such as funnel visualization, where visitors came from (referrers), how long they stayed on the website and their geographical position. It also provides more advanced features, including custom visitor segmentation. Google Analytics e-commerce reporting can track sales activity and performance. The e-commerce reports shows a site›s transactions, revenue, and many other commerce-related metrics

III. Conclusion

Web mining is an application of data mining and very useful extraction of useful information from web sites and server log file. There are 3 types of web mining such as web content mining, web structure mining and web usage mining. This chapter describes about basics of web mining and real time applications such as B2C E-commerce Amazon.com,Auction Behavior eBay,CiteSeer-Digital Library and Autonomous Citation Indexing, personalizing web- yahoo, Web Communities—AOL,Web Search—Google.

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Optimization of Process Parameters Using Taguchi Approach in Shot Peened Ti6Al4V Alloy for Implants

[1]K. Balasubramanian, [2]R.A. Hari Baalaaji, [3]C. Krishnaraj, [4]R. Haridass

[1]Department of Mechanical Engineering, Sri Krishna College of Engineering and Technology, Coimbatore-641008, India

skcetbalu@gmail.com

[2-4]Department of Mechanical Engineering, Karpagam College of Engineering,Coimbatore-641032

ABSTRACT

The biomedical implants and many engineering applications demand materials with hard surface and tough core. In the present study, the enhancement of this combination of properties was achieved in Ti6Al4V alloy by severe plastic deformation process called shot peening process. The process parameters were optimized using Taguchi L9 orthogonal design of experiments. The shot peening pressure, shot peening distance and shot peening duration were the parameters taken into consideration as they are directly related to the energy imparted to the surface during the process. The optimal levels were independently determined with reference to surface hardness of the material. The predicted optimal values of surface hardness were confirmed by experiments. Analysis of variance (ANOVA) showed that peening distance was found to be more dominant than the other parameters. Results from scanning electron microscope (SEM) analysis was used to explain the enhancement of properties.

Keywords: Shot peening process, Taguchi, ANOVA, hardness, optimization

1. Introduction

The biomaterials field has a long history, dating back to ancient civilizations such as the Egyptians and Romans who utilized gold and iron for dental applications and wood for toe replacements over 4000 years ago. Following World War II, new materials like Nylon, Teflon, silicone, stainless steel, and titanium came into play. In the early years of human existence, there was a complete lack of scientific knowledge. However, with advancements in diagnostic tools and increased

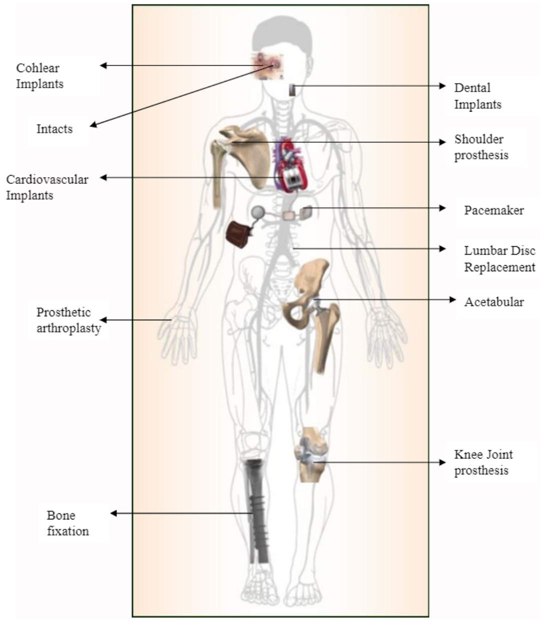

Fig. 1: Bio-implants

understanding of materials and surgical procedures, implant technology has gained greater significance. The commonly used bio-implants are depicted in Figure 1.

A diverse range of materials, including metals, alloys, polymers, ceramics, and composites, has been widely employed in the production of bio-implants. However, the intricate challenge lies in the fact that the physical and chemical traits of these implants encounter diverse biological environments, and their interaction with tissues and bones is a complex issue.

When choosing biomaterials, a crucial criterion is their acceptance by the human body, ensuring they do not induce adverse effects immediately after surgery or during postoperative conditions. To meet these requirements, biomaterials must possess sufficient mechanical strength, high corrosion and wear resistance, and biocompatibility. The longevity of bio-implants is paramount, necessitating their ability to endure for an extended period without failure, ideally lasting until the end of a person's life. This necessitates a minimum service period, typically ranging from 15 to 20 years for older patients and over 20 years for younger patients. The success of a biomaterial or implant is heavily contingent on these aforementioned factors.

The materials presently in use, namely stainless steel, chromium-cobalt alloy, and titanium alloy, were chosen in accordance with the aforementioned criteria.

Despite their effective performance within the human system, these materials typically exhibit failures within approximately 12-15 years, necessitating repeat surgery to restore bodily functions. The causes of their failure include mechanical, chemical, tribological, manufacturing, and biocompatibility issues. Among these challenges, implant failure due to wear and corrosion remains a particularly formidable problem.

The primary categories of biomedical alloys consist of stainless steel, cobalt-chromium alloys, and titanium alloys. However, the use of these materials presents challenges due to the generation of metal debris and ions, which can provoke adverse biological reactions. Over the past three to four decades, stainless steel, cobalt-chrome-based alloys, and titanium alloys have been successfully employed as implant materials. Nevertheless, issues such as crevice/pitting corrosion in stainless steel and cobalt-chromium alloys lead to the release of elements like Ni, Cr, and Co into the human body, posing harm. Similarly, wear of titanium alloy results in the release of toxic V into the body. Consequently, engineers and scientists have consistently strived to enhance the surface properties of biomaterials to reduce implant failures caused by poor cell adhesion and ion leaching due to wear and corrosion.

In the intricate and sensitive biological system, preventing corrosion using inhibitors proves challenging. Therefore, various coating methods, including chemical treatment, plasma ion implantation, laser melting (LSM), laser alloying (LSA), laser nitration, physical vapor deposition (PVD), and surface texturing, have been adopted. Likewise, surface modification techniques such as surface machining, sandblasting, acid etching, electro-polishing, anodic oxidation, plasma-spraying, and the application of biocompatible/biodegradable coatings are employed to mitigate corrosion, enhance osseointegration, and improve biocompatibility.

Shot peening is a cold working technique employed to generate a compressive layer and alter the mechanical characteristics of metal. By subjecting a surface to peening, it undergoes plastic deformation, leading to modifications in its mechanical properties. This process finds application in various components such as cams, gears, camshafts, coil springs, biomedical implants, and more.[1,2] Shot peening contributes to the enhancement of mechanical properties, including fatigue life, tensile strength, hardness, as well as corrosion resistance and resistance to cracking in metal parts. Various factors, such as pressure, mass flow rate, angle of impact, distance from the target, time of shot peening, shot size, and the type of shot, exert influence on the shot peening process.[3]

Improper selection of shot-peening parameters can lead to detrimental effects on mechanical properties, particularly fatigue.[4,5] This highlights the significance of carefully choosing shot-peening parameters to enhance mechanical properties. Consequently, it is crucial to assess the impact of shot-peening parameters on mechanical properties and to make optimal and appropriate selections for improved outcomes.

Design of Experiments (DOE) encompasses a set of statistical methods utilized to investigate the relationships between input variables (independent variables) and their interactions affecting a response variable (dependent variable).[6] Full factorial designs, while comprehensive, necessitate a large number of experiments as the quantity of process parameters increases, leading to elevated experimental costs and time. Robust design represents an engineering methodology aimed at optimizing both product and process conditions to be less susceptible to various sources of variation, ultimately yielding a high-quality product with reduced developmental costs.[7] The Taguchi method offers a straightforward, efficient, and systematic approach for optimizing designs concerning performance, quality, and cost.[8] By integrating engineering and statistical knowledge, Taguchi has developed a technique for optimizing design and manufacturing processes to achieve high-quality outcomes with minimized costs and time. The Taguchi method is a valuable tool for robust design, aiding in the identification of process parameters and their optimal levels to achieve the desired quality characteristics and limit the number of experiments required for optimization.[9]

Various approaches, including numerical, analytical, and experimental methods, can be employed to assess the effects of shot peening.[10,11] The analytical approach faced limitations, prompting extensive empirical research in the field of shot peening.[12,13] Numerical simulation offers a cost and time-effective alternative to experimental tests, encompassing both single-shot scenarios[14,15] and multi-shot simulations.[16,17] Notably, recent work by Ghasemi et al.[18], Miao et al.[19], and Mahmoudi et al.[20] has introduced models featuring fully randomized scattering of shots, mirroring real-world shot peening and contrasting with uniformly distributed shot models. Beyond the modeling of shot peening, researchers have also delved into studying its optimal parameters. Nam et al.[21] and Al Sumait[22] have identified the optimal coverage for maximizing fatigue life. Petit-Renaud et al.[23] and Romero et al.[24] optimized the objective function to achieve maximum compressive stress. Vielma et al.[25] and Unal[26] considered roughness as their objective function. Bhuvaraghan et al.[27] explored multi-objective shot-peening using a genetic algorithm approach, optimizing compressive residual stress while taking into account work hardening and roughness within specific limits.

Baragetti[28] simultaneously optimized maximum compressive stresses, surface roughness, compressive residual stress depth, and maximum compressive stress depth. Seddik et al.[29] successfully optimized two objective functions: the damage variable and compressive residual stress for the shot-peening process.

The Taguchi method proves to be an effective strategy for minimizing the number of experiments and cutting down on time and costs.[30] In this methodology, identifying suitable levels for each process parameter is crucial, and a standard orthogonal array is chosen accordingly. Applying the Taguchi approach, George et al.[31] optimized shot-peening intensity, while Khani et al.[32] determined the optimal parameters for shot peening low carbon steel using Taguchi's technique. In[33], the Taguchi method is employed to analyze the effects of shot peening on grain size, hardness, and residual stress. Notably, in all the mentioned research, objective functions were individually examined. The Taguchi method stands out for its high efficiency and speed in determining effective parameters and optimal levels.

In this investigation, the Taguchi Design of Experiments (DOE) methodology was employed to assess the impact of shot peening parameters (pressure, distance, and time) on hardness. The aim was to identify the optimal configuration of these parameters to attain the highest possible surface hardness.

2. Experimental Work

2.1 Materials

The focus of this study revolves around the Ti6Al4V alloy, selected as the primary material due to its versatility across various industries, such as aerospace and biomedical applications. The base material for the experimental investigation measured 10 mm × 10 mm × 5 mm in dimensions. The chemical components of the base material are outlined in Table 1.

Table 1: Chemical elements of the base material

Chemical elements	*Al*	*V*	*Fe*	*O*	*Ti*
Wt.%	5.8	3.9	0.4	0.15	Balance

2.2 Shot Peening Processes

The experimental procedures involved the utilization of a pressure blaster PB9182 SPL machine for shot peening, as depicted in Figure 1. The specific parameters selected for the shot peening process are detailed in Table 2. The nozzle was positioned perpendicular to the specimen during the procedure, and stainless steel shots measuring 0.4 mm were employed for the shot peening process, as illustrated in Figure 2.

Fig. 1: Shot peening process

Fig. 2: Stainless steel shots

2.3 Surface Hardness Measurements

The Vickers microhardness test was employed to ascertain the surface hardness of the materials. Both the surface-treated shot-peened specimen and the non-treated specimen underwent hardness measurement using a force of 500 g and a 15-second holding period.

2.4 Design of Taguchi Experiment

The aim of the study was to optimize the parameters of the shot peening process to attain elevated hardness levels in the material under investigation.

2.5 Identification of Process Parameters and their Levels

A series of preliminary experiments were carried out to establish the optimal range for each factor, which was subsequently divided into three levels. The chosen process parameters for this experimental investigation include:

Peening pressure (bar): Air pressure is utilized to propel the shot stream onto the specimen's surface, directly influencing the shot speed and, consequently, the energy transfer from the shot to the specimen's surface.

Peening distance from the target (specimen)

Peening time (seconds)

The process parameters and their corresponding levels are outlined in Table 2.

Table 2: Process parameters and their levels for shot peening process					
Factor	*Code*	*Unit*	*Level 1*	*Level 2*	*Level 3*
Pressure	P	Bar	2	3	4
Distance	D	Mm	50	100	150
Time	T	Sec	10	20	30

2.6 Orthogonal Array

Taguchi's parameter design stands out as a pivotal step in process optimization. Orthogonal arrays (OA) play a crucial role in determining the minimal and practical number of experiments for a specific set of factors. To fulfill the condition of the minimum number of experiments with three factors, each having three levels, an L9 Orthogonal Array was chosen. The array is detailed in Table 3, and its selection has significantly reduced the required experiments from 27 to just nine, without compromising accuracy significantly. Experimental data for hardness and S/N ratios are provided in Table 4.

Table 3: Standard L9 orthogonal array			
Trail No.	*Pressure*	*Distance*	*Time*
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

3. Results and Discussion

3.1 Signal-to-noise Ratios (S/N Ratios)

The Taguchi method is employed to identify the experimental condition with the least variability as the optimal condition. This variability is quantified through the signal-to-noise ratio (S/N ratio, denoted by η). The experimental condition exhibiting the maximum S/N ratio is deemed optimal since the variability of the characteristics is inversely proportional to the S/N ratio.[34] The experiments adhered to the principles of design of experiments, and the objective function in this study is the maximization of hardness. Consequently, the S/N ratios were computed using the "larger the better" approach.

$$\eta(\mathrm{dB}) = -10\log_{10}\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}$$

where y_i is the i^{th} value of the response variable (surface hardness)

The experimental data were transformed into their respective means and S/N ratios, as illustrated in Table 4.

Table 4: Standard L9 orthogonal array with observations and S/N ratio

Trail No.	*Pressure (bar)*	*Distance (mm)*	*Time (sec)*	*Surface hardness (VHN)*	*S/N ratio for hardness*
1	2	50	10	359	51.1019
2	2	100	20	487	53.7506
3	2	150	30	343	50.7059
4	3	50	20	530	54.4855
5	3	100	30	466	53.3677
6	3	150	10	351	50.9061
7	4	50	30	411	52.2768
8	4	100	10	381	51.6185
9	4	150	20	361	51.1501

The average means and S/N ratios for all levels of surface hardness are presented in Table 5. Employing the maximization criteria, it was determined from the mean and S/N ratio values that the optimal level setting for surface hardness is $P_2D_2T_2$.

Table 5: Response Table for Means (Left) and Signal-to-Noise Ratios (Right) of Surface Hardness

Level	*P*	*D*	*T*
1	396.3	433.3	363.7
2	**449.0**	**444.7**	**459.3**
3	384.3	351.7	406.7
Delta	64.7	93.0	95.7
Rank	3	2	1

Level	*P*	*D*	*T*
1	51.85	52.62	51.21
2	**52.92**	**52.91**	**53.13**
3	51.68	50.92	52.12
Delta	1.24	1.99	1.92
Rank	3	1	2

3.2 Analysis of Variance (ANOVA)

The analysis of variance (ANOVA) provides a comprehensive insight into the impact of specific process parameters on the response. Therefore, ANOVA was employed to statistically differentiate significant factors from insignificant ones. The ANOVA for the means of surface hardness is presented in Table 6.

Table 6: ANOVA Table for Means (Surface Hardness)					
Source	***DF***	***% Contribution***	***Adj SS***	***Adj MS***	***F-Value***
Pressure	2	1.4	21.6	10.8	0.09
Distance	2	64.88	1000.4	500.2	4.12
Time	2	17.98	277.35	138.68	1.14
Error	2	15.73	242.56		
Total	8		1542		

The main effects for means and S/N ratios of surface hardness are depicted in Fig. 2. An F-test was conducted to assess the significance of the process parameters. The results of the F-test indicated that distance was found to be statistically significant in affecting surface hardness of the Ti6Al4V alloy with a contribution of 65% while the other parameters were insignificant.

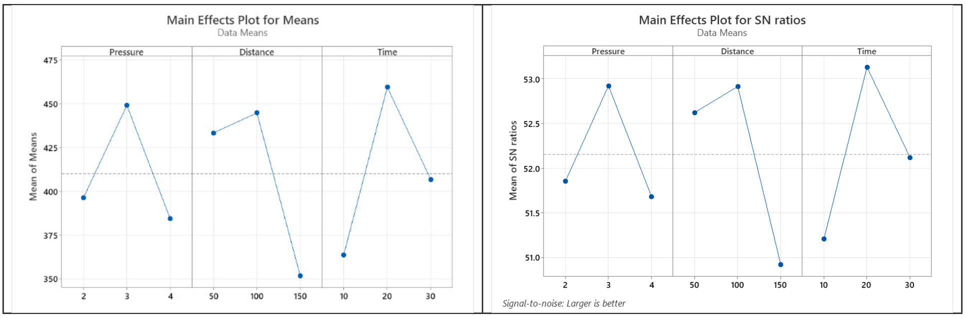

Fig. 2: Main effects plot for means and S-N ratios for surface hardness

3.3 Predicted Values

The mean values of the factors at their respective levels were extracted from Table 5 for surface hardness. The surface hardness values for the optimal level of process parameters were predicted using the formula provided below:

$$\text{Surface Hardness (predicted)} = P_2 + D_2 + T_2 - 2Y$$
$$= 449 + 444.7 + 459.3 - 2(409.88)$$
$$\approx 533.24 \text{ Hv}$$

where P_i, D_i and T_i are the average mean values of shot peening pressure, peening distance and peening duration of treatment at their i^{th} levels respectively, and Y is the overall mean

3.4 Confirmation Experiments

The confirmation experiment was conducted on two different samples with the process parameters set at their optimal levels, specifically, a peening pressure of 3 bar, a peening distance 100 mm and a peening duration of 20 seconds, for the confirmation of surface hardness. The average surface hardness values were determined to be 489.8 Hv. This value falls almost within ±8% of the predicted mean values.

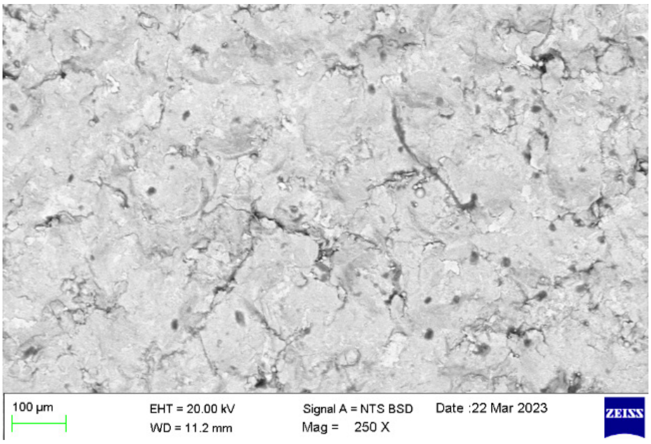

Fig. 3: SEM image of Ti6Al4V alloy

3.5 SEM Analysis

Vickers microhardness measurements demonstrated an enhancement in the surface hardness of shot peened Ti6Al4V alloy, increasing from 341.1 Hv in the non-treated specimen to 489.8 Hv when subjected to a shot peening treatment involving a 3 bar peening pressure, 100 mm peening distance and 20 seconds peening duration. This hardness represents a 43% improvement compared to the non-treated condition. Shot peening (SP) is known for inducing work-hardening, leading to a refined domain size, high-density dislocations, and even the formation of a nano-crystalline layer on the surface.[35] A SEM micrograph of Ti6Al4V alloy before shot peening and after shot peening treatment are depicted in Fig. 3.

4. Conclusions

Based on the aforementioned discussion, the following conclusions can be drawn:

- The parameters of the shot peening process were optimized for surface hardness.
- ANOVA revealed that all three process parameters, peening pressure, peening distance and peening duration of treatment, influence the surface hardness. The peening distance was identified as the dominant factor influencing surface hardness.

- Taguchi analysis indicated that the optimal combination of 3 bar peening pressure, 100 mm peening distance and 20 seconds peening duration of treatment yielded the maximum predicted surface hardness of 533.24 Hv.
- Confirmation experiments conducted with these optimal settings on two different samples resulted in an average hardness of 489.8 Hv in decent agreement with the predicted values (533.24 Hv).
- SEM analysis suggested that the observed hardness enhancement is a consequence of grain refinement induced by severe plastic deformation during shot peening process.
- It was seen that the fatigue strength of a specimen depends on the surface hardness. The fatigue strength of the material increases with increasing surface hardness. Shot peening improves the surface hardness leads improvement of the fatigue strength.

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Functionalized Magnetic Nanosystems for Diagnostic Tools and Devices
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Chapter 12 - Functionalized magnetic nanosystems for medical imaging

N. Mahender Reddy [a], Gubbala V. Ramesh [a], Shravan Kumar Reddy [b], D. Saritha [a]

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Abstract

There has been a long history of research into the diagnostic potential of functionalized magnetic nanoparticles (FMNPs). FMNPs' potential stems from their many attractive characteristics, including their large surface/volume ratio, dispersibility, capacity to interact with different molecules, and superparamagnetic capabilities. They have found several medical uses, especially in the magnetic resonance imaging (MRI) field. For MRI, iron oxide nanoparticles (IONPs) are shown great promise as a substitute for traditional contrast agents (CAs). Because of their superior magnetic characteristics and good biocompatibility, they have been the subject of substantial research as CAs. In addition, molecular MRI is now feasible because their surfaces are voluntarily functionalized with a wide diversity of ligands such as sugars and peptides. IONPs have expanded beyond their original use in cancer diagnosis to include other areas such as the early identification of thrombosis and the detection of brain inflammation. However, there are other obstacles that IONPs must overcome before they can successfully enter the market. Research has focused on improving the safety profile and the magnetic characteristics of FMNPs as a means of overcoming these obstacles. Adding additional metals, including cobalt (Co) and manganese (Mn), to FMNPs is a significant method for lowering the amount of iron (Fe) released into the body and producing multimodal nanoparticles with novel characteristics. In another direction, FMNPs containing metals other than Fe that are

known to have excellent imaging characteristics may be developed. The development of flexible multinode platforms (FMNPs) that may be used to integrate MRI and other imaging modalities to provide more comprehensive diagnostic tests seems to be the future of this study.

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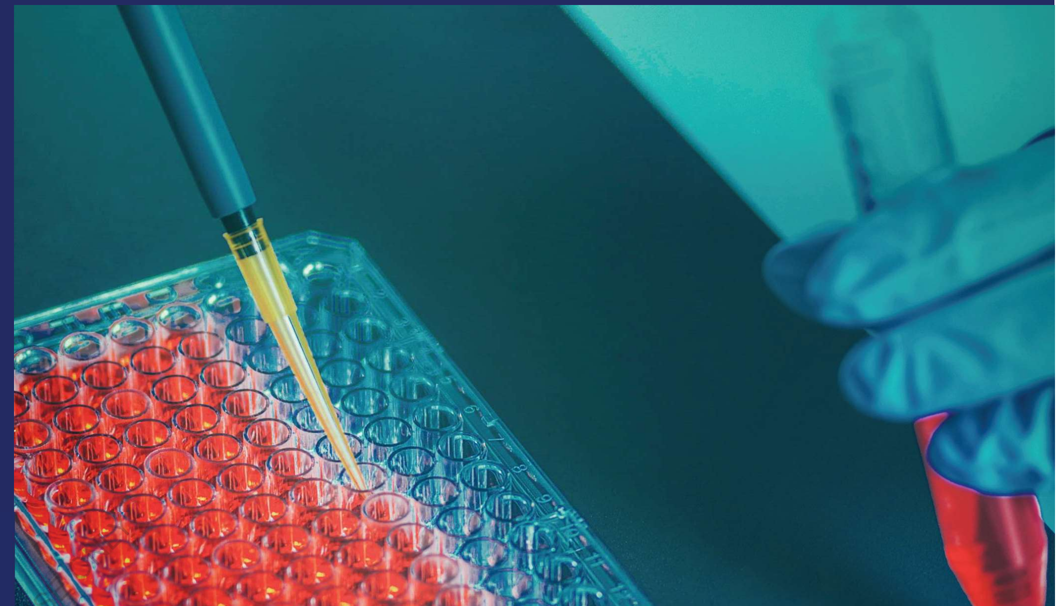
3D printing, also known as additive manufacturing, has gained widespread recognition for its applications in tissue engineering, art, and architectural modeling. The focus on 3D printing in tissue engineering is growing among researchers due to its ability to manufacture highly accurate and personalized scaffolds rapidly. Scaffolds, crucial for tissue regeneration and repair in regenerative medicine, are crafted from various materials such as natural, synthetic, and copolymer polymers. These scaffolds provide a supportive structure for cell nurturing and differentiation, facilitating the regeneration of damaged tissues or organs. This paper comprehensively explores scaffold materials, fabrication methods, and the role of 3D printing in tissue engineering applications, emphasizing the crucial interplay between material properties, scaffold architecture, and the specific requirements of the target tissue for successful regeneration and integration of functional tissue constructs.



Dr. D. Saritha

Tissue Engineering: Crafting Polymer Scaffolds with AM Techniques

Dr. D. Saritha holds the position of associate professor in the Department of Chemistry at Chaitanya Bharathi Institute of Technology, Hyderabad. Her doctoral studies were completed at the Indian Institute of Technology Madras, and she possesses expertise in both additive manufacturing and material science.

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Tissue Engineering: Crafting Polymer Scaffolds with AM Techniques

D. Saritha

*Department of Chemistry, Chaitanya Bharathi Institute of Technology, Gandipet, Hyderabad TS- 500075, India

Abstract

Three-dimensional (3D) printing, often known as additive manufacturing, is an expertise that enables adapted manufacture using computer-assisted design. 3D printing approaches have gained recognition in tissue engineering, art, and architectural modeling applications. The 3D printing application to tissue engineering is attracting the attention of numerous researchers. A benefit of 3D printing in creating a scaffold is its speedy manufacturing, high accuracy, and capacity for producing personalized items. Scaffolds are indeed produced using several materials, including natural, synthetic, and copolymer polymers, to enable tissue regeneration and repair in the regenerative medicine field. Scaffolds offer a supportive structure for cells to nurture and differentiate, aiding in regenerating damaged tissues or organs. This paper likely discusses the comprehensive landscape of scaffold materials, their fabrication methods, and the 3D printing role

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in tissue engineering applications. It is crucial to consider the interplay between material assets, scaffold architecture, and the precise necessities of the target tissue to ensure the successful regeneration and integration of functional tissue constructs. The range of manufacturing techniques and technical requirements make choosing a scaffold construction process difficult. The internal scaffold architecture, porosity, which creates interconnected pores, and appropriate mechanical strength are all important in designing and developing tissue engineering scaffolds. The 3D printing expertise produces high-resolution scaffolds and precisely controlled dimensions compared to conventional processes. This technology is also simple to use, inexpensive, and offers quick printing.

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Keywords: 3D printing; polymer scaffolds; Tissue engineering; Fabrication.

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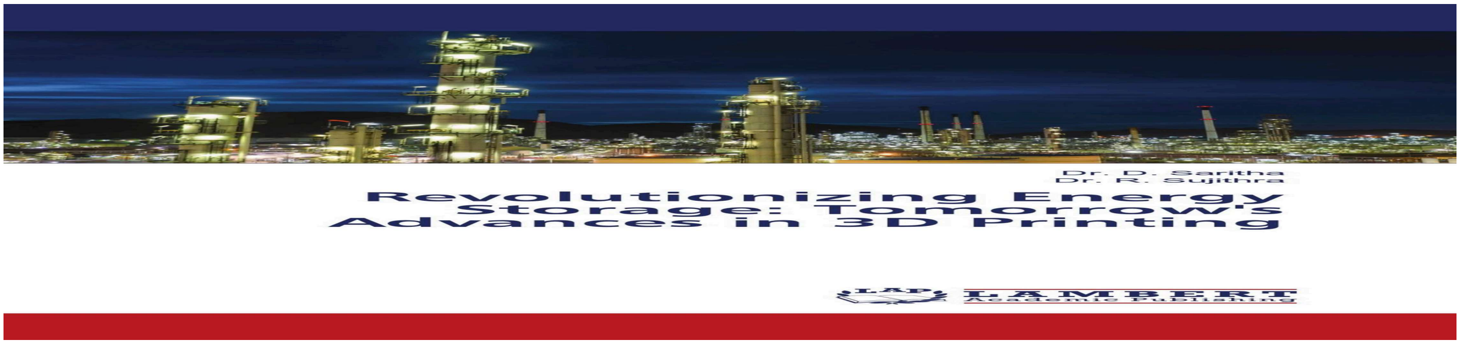

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Chapter 25
Towards Green Chemistry Quantum Computing Applications in Chemical Synthesis

N. Srivani
Sumathi Reddy Institute of Technology for Women, Hasanparthy, India

Vinay Chandra A.
Synocules Laboratories Pvt. Ltd., India

Kola Ramesh
https://orcid.org/0000-0002-6495-6939
Chaitanya Bharathi Institute of Technology (Autonomous), India

Y. B. Kishore Kumar
Mohan Babu University, India

ABSTRACT

In the trouble to achieve chemical emulsion that's both sustainable and kind to the terrain, the objectification of quantum computing has a major pledge. In this work, the lately arising content of green chemistry is delved, with a particular emphasis placed on the operations of volume computing in chemical mixing. Quantum calculating provides an unknown position of computational capacity, with the capability to bluffing molecular structures and responses with an unfathomable position of slyness and effectiveness. researchers can make new chemical pathways, optimize response circumstances The purpose of this work is to present a review of current advancements in quantum computing applied to chemical emulsion and to examine the implicit implications for manufacturing processes that are more environmentally friendly and sustainable. This will be fulfilled through the community of volume computing and the generalities of green chemistry.

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INTRODUCTION

When it comes to working global enterprises similar as climate change, pollution, and the drop of coffers, the field of chemistry plays an essential part. Traditional chemical emulsion procedures generally involve dangerous reagents, induce significant quantities of waste, and need a significant quantum of energy, all of which contribute to the declination of the terrain. In response to this, the conception of green chemistry has surfaced, which advocates for the development of chemical products and processes that have a minimum impact on the terrain while contemporaneously maximising their effectiveness and their capacity to be sustainable J. Smith and A. Johnson. (2020). The advance paradigm in calculating technology known as Quantum computing has enormous pledge for the advancement of green chemistry. It'll give essential tools for molecular modelling, design, and optimisation, which will allow for the advancement of green chemistry. The purpose of this composition is to probe the crossroad of green chemistry with quantum computing, with a particular emphasis on the operations of chemical emulsion technology.

A significant paradigm shift has passed in the field of computational chemistry as a result of the operation of volume computing in chemical exploration P.S. Ranjit, et al.(2022). Because of their computational complexity and incapability to directly describe large-scale chemical systems, traditional computational approaches, similar as molecular dynamics simulations and density functional propositions, are confined in their capability to model chemical systems. When it comes to distinction, quantum computing makes use of the principles of quantum mechanics to do sophisticated calculations exponentially more briskly than classical computers. This makes it possible to directly predict molecular packages, response mechanisms, and material gestures than was before possible. Using quantum algorithms and quantum simulations, researchers can speed up the process of discovering and optimizing chemical responses and accessories that are safe for the terrain Christo Ananth, Denslin Brabin, Sriramulu Bojjagani(2022).

also, the field of quantum computing presents new openings for the development of catalysts, cleansers, and response conditions that are suited to the operations of green chemistry R. Patel et al.(2018). The analysis of huge chemical response networks and the identification of catalytic routes with great selectivity and effectiveness are both now possible thanks to Quantum algorithms. likewise, the operation of machine knowledge algorithms facilitates the prophecy of chemical reactivity and the optimization of response circumstances, which eventually results in the development of fresh sustainable emulsion routes X. Wang and Y. Li(2018). volume simulations, on the other hand, make it possible to directly pretend molecular connections and electrical structures, which in turn helps in the development of environmentally friendly accessories that are integrated into climate-controlled products. The confluence of green chemistry with volume computing opens up preliminarily unexplored avenues for the modification of chemical systems and the creation of environmental sustainability. The purpose of this work is to probe the current state of the art in quantum computing procedures for chemical mixing and to explain the prospects for enhancing green chemistry through methodologies that are enabled by quantum computing [6].

RELATED WORK

The convergence of Quantum computing and green chemistry has garnered a significant Quantum of attention over the course of the past few years. A great number of studies have been carried out to explore the implicit operations and counteraccusations of Quantum computing in connection to chemical confla-

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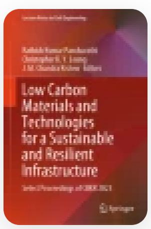

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Author information

Authors and Affiliations

Department of Civil Engineering, CBIT, Hyderabad, 500075, India

N. R. Dakshina Murthy, T. Vasudeva Rao & K. J. Rao

Department of Civil Engineering, Vasavi College of Engineering (A), Hyderabad, India

B. Sridhar

Smart Build Prefab Pvt Ltd, Hyderabad, India

Simhadri Raju

Corresponding author

Correspondence to N. R. Dakshina Murthy .

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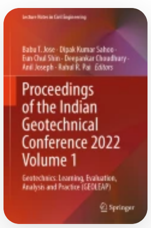

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Author information

Authors and Affiliations

Chaitanya Bharathi Institute of Technology, Hyderabad, 500075, India

Raghava A. Bhamidipati

C V Raman Global University, Bhubaneswar, 752054, India

Janarul Shaikh, Mayank Das, Subha Prakash Beura & Pritish Das

Corresponding author

Correspondence to Raghava A. Bhamidipati .

Editor information

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Preface: International Conference on Advances in Civil Engineering (ICACE) 2022

Sandip A. Kale [1], K Jagannadha Rao [2] and Yuvaraj L. Bhirud [3]

[1]*Technology Research and Innovation Centre, Pune, India*
[2] *Chaitanya Bharathi Institute of Technology (A), Gandipet, Hyderabad, India*
[3]*LSKBJ College of Engineering, Chandwad, Nashik, India*

International Conference on Advances in Civil Engineering 2022 (ICACE 2022) was hosted by Department of Civil Engineering, LSKBJ College of Engineering, Chandwad, Nashik, India (affiliated to Savitribai Phule Pune University, Pune) and organized by Technology Research and Innovation Centre, India in association with Chaitanya Bharathi Institute of Technology (A), Hyderabad, India, Civil Engineering Department, Sant Gajanan Maharaj College of Engineering, Mahagaon, Maharashtra, India (affiliated to Shivaji University, Kolhapur), Civil Engineering Department, Accra Technical University, Ghana and Academy of Nanotechnology and Waste Water Innovations, Johannesburg, South Africa on 20-22 December 2022.

This three day online international meeting provided a platform to various worldwide researchers, and academicians engaged in the field of civil engineering with the motive of exploring the research to drive the World towards a sustainable future. ICACE 2022 received abstracts from various countries such as Algeria, Bangladesh, Canada, China, Cyprus, Germany, Greece, India, Indonesia, Iran, Malaysia, Morocco, New Zealand, Oman, Peru, Philippines, Russia, Singapore, Somalia, Switzerland, Turkey, United Arab Emirates and VietNam. Selected research and reviews were presented by various researchers during these three days in different online sessions.

In this conference 6 keynote speeches were delivered by renowned professors and scientists include Dr. Pijush Samui, India; Dr. Mo Kim Hung, Malaysia; Dr. Rita Yi Man Li, Hong Kong; Prof. Phoebe Koundouri, Greece; Dr. Selda Oterkus, United Kingdom; Dr. Ilenia Farina, Italy.

Among the presented and peer reviewed 60 papers, 31 papers are accepted and included in this volume. The papers in this volume are organized in two sections, 1) Materials and Structural Mechanics, and 2) Computational Analysis and Optimizations in Civil Engineering. We feel, these papers will provide a valuable contribution in the field and readers will receive this content for their future research activities.

The conference organizers and associate organizers are thankful to all authors, keynote speakers, scientific committee members, session chairs, session coordinators, supporting team members and organizing committee members for contributing actively and whole heartily in successful completion of the conference throughout the various stages. We also express our gratitude towards the AIP Publishing for providing support to publish the ICACE 2022 papers in AIP Conference Proceedings.

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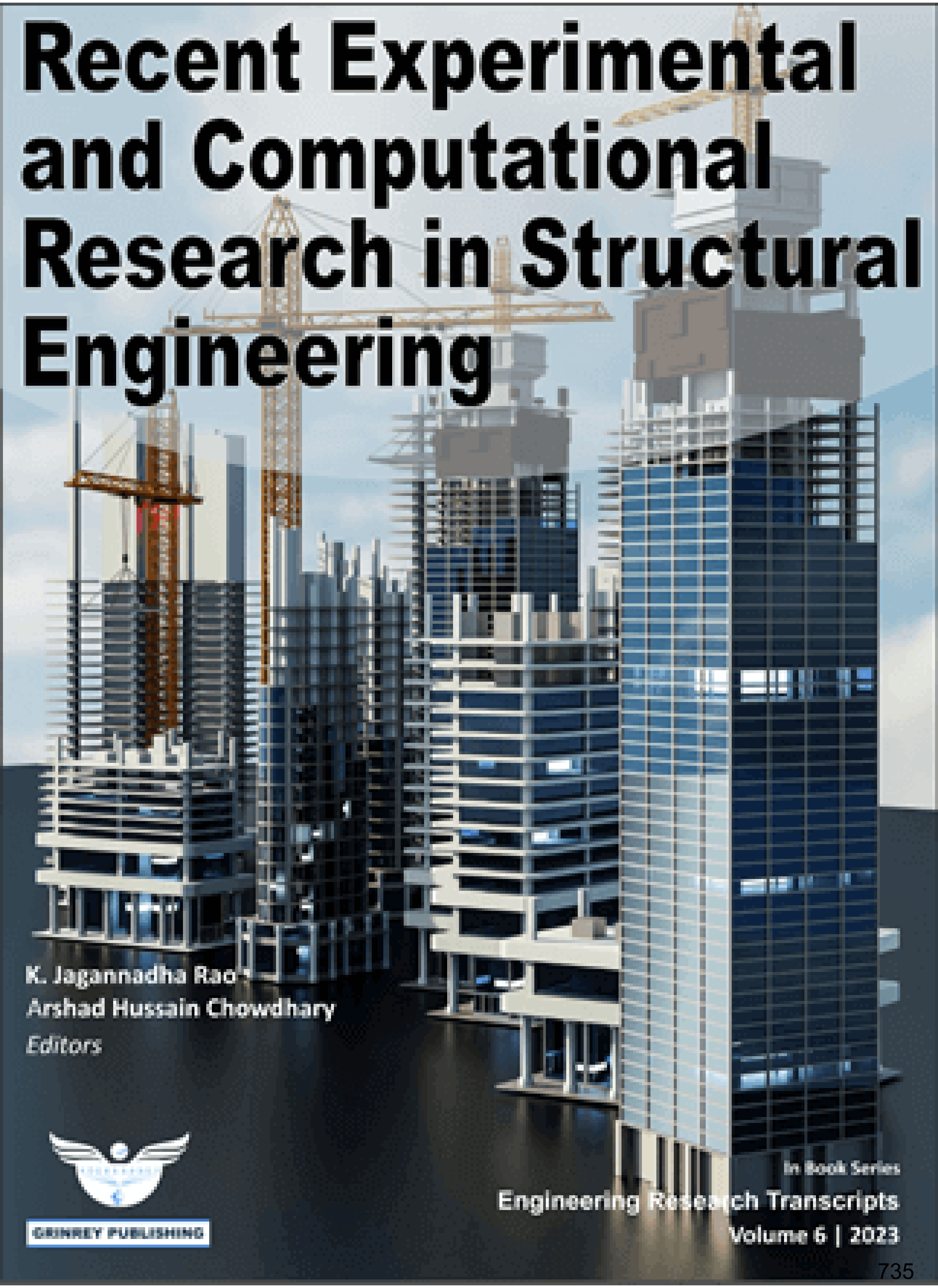

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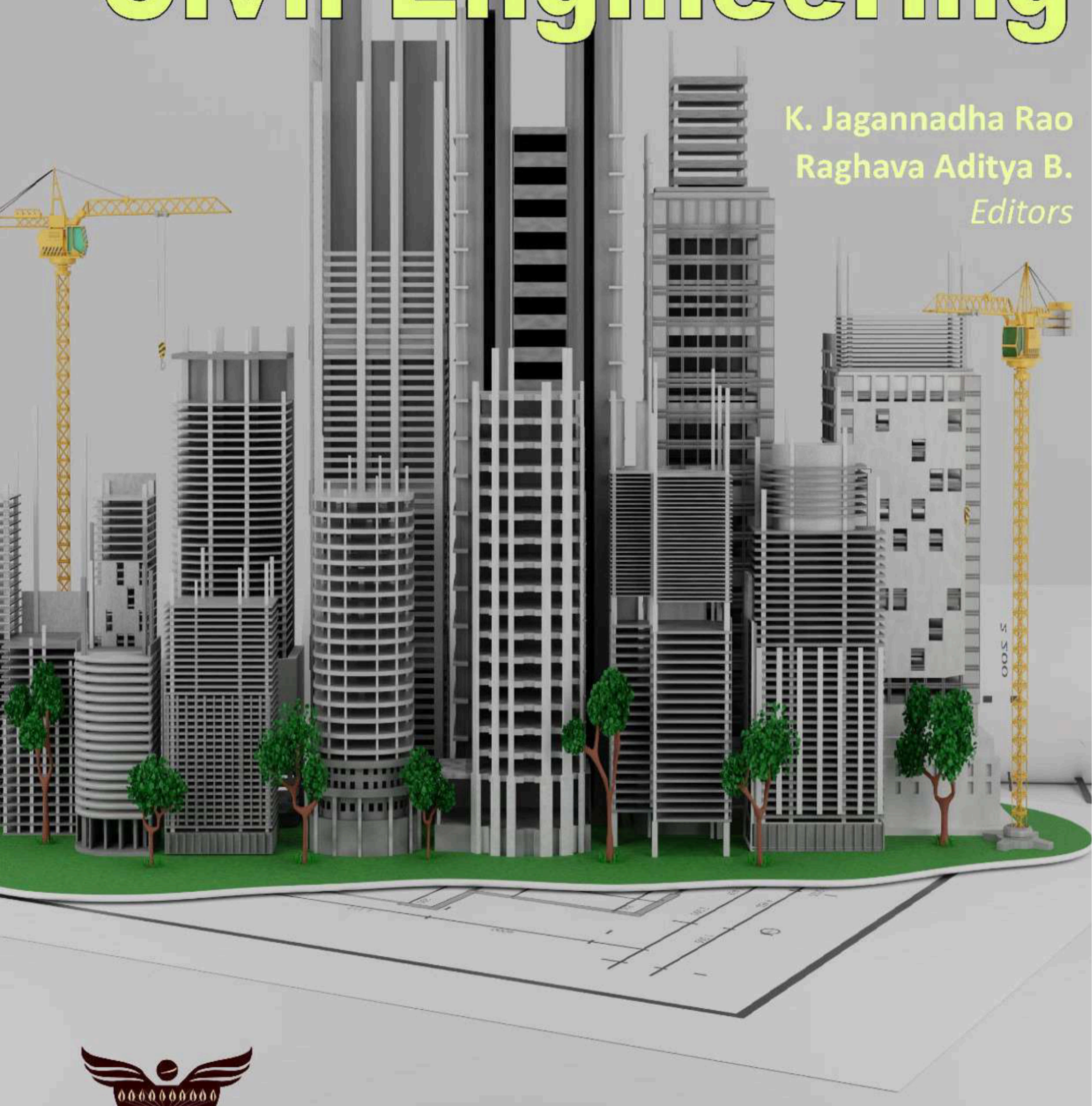

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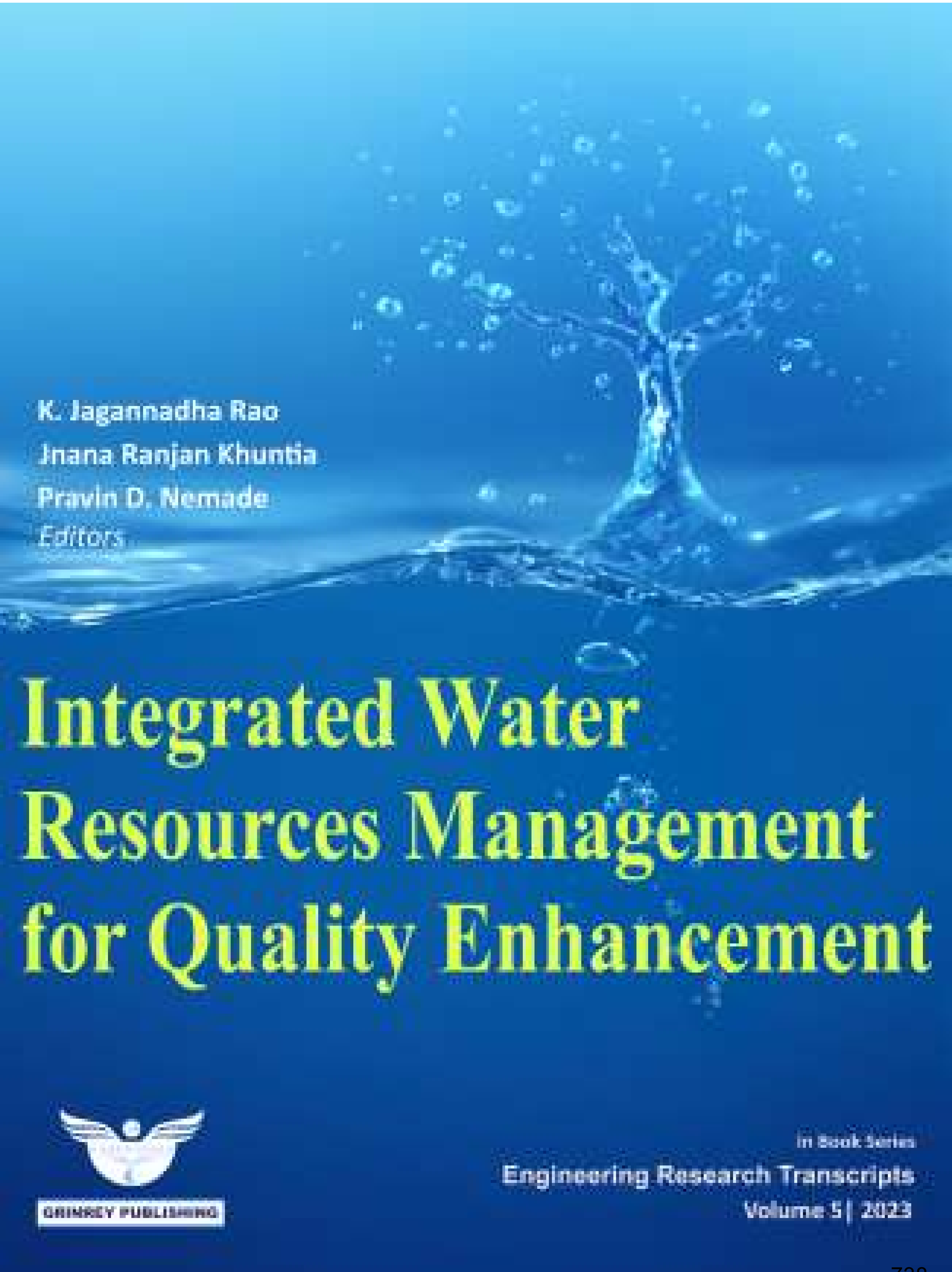
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2D Analysis of Slope Stability Using Limit Equilibrium Analysis and Finite Element Analysis

S. Sravya, Angshuman Das, Koteswaraarao Jadda, and Dinesh Gundavaram

1 Introduction

Slopes play a vital role in the construction of highways and railway embankments, earth dams, levees, and canals. In hilly areas, slopes along the highway are more susceptible to landslides. Slope failure refers to the sudden movement or collapse of soil, rock, or debris on a sloping surface. It is a common geotechnical problem that can occur due to various factors, including natural phenomena such as rainfall, earthquakes, and erosion, or human activities like excavation, mining, and construction. Slope failure can have severe consequences, including environmental deterioration, property damage, and loss of life. Some of the significant instances where slope failures occurred in India include Agumbe ghat in Karnataka (2019), two landslides along the National Highway 1-A in Ladakh Region of Jammu and Kashmir (2023), Malin landslide in Maharashtra (2014), Kedarnath landslide at Uttarkhand (2013), etc. Therefore, it is crucial to perform slope stability analysis to identify potential failure modes and implement appropriate measures to prevent slope failure.

Slope stability analysis can be performed using empirical or analytical approaches for evaluation the stability of excavated or natural slopes in soil and rock, rock-fill or earthen dams, and embankments. 2D approaches were widely adopted by several engineers for slope stability analysis due to their simplicity [1–3]. 2D slope stability analysis use simple geometry of 3D slope by considering the plain strain or axisymmetric conditions. In past decades the 2D slope stability analyses have

S. Sravya · A. Das (✉)
Chaitanya Bharathi Institute of Technology, Hyderabad, Telangana 50075, India
e-mail: dasangshuman6@gmail.com

K. Jadda
Dr B R Ambedkar National Institute of Technology Jalandhar, Jalandhar, Punjab 144011, India
e-mail: Jaddak@nitj.ac.in

D. Gundavaram
Indian Institute of Technology Hyderabad, Hyderabad, Telangana 502285, India

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Interlinking of Rivers (Godavari–Krishna–Pennar–Cauvery)

Rohitha, Sudheera, Renuka, Manisha, and Kamalini Devi

Abstract The present study examines the purpose of interlinking of rivers, which benefits mankind. It primarily focuses on interlinking the rivers by creating a system of manually developed canals where the river water is not attainable. The proposal is based on diverting the surplus water from the rivers receiving the high floods to the deficit rivers by connecting the manually developed canals. So, it will assist in diverting surplus water to the deficit rivers in case of necessity. The idea is to design canals that connect the rivers Godavari, Krishna, Pennar, and Cauvery to control floods and use surplus water for irrigation and other purposes. Manning's method is used for the design of canals. Flood frequency analysis has been shown for these four rivers. This analysis played a major role in executing the plan. According to the flood data, the rivers Pennar and Cauvery have had very low floods over the years, whereas the rivers Godavari and Krishna experience the high number of floods. So, the flood water is set to be diverted to the rivers Pennar and Cauvery. These auspicious results have enlarged the potential of success in planning. The main objectives are to draw water from the Godavari River to the Krishna River (Detailed notes on "Krishna River" by Wikipedia), from the Krishna River to the Pennar River, and from Pennar River to the Cauvery River. This can be ended by linking the reservoirs situated across these rivers by the link canals.

Keywords River basin · Tributaries · Diversions · Reservoirs · Canals · Flood frequency analysis · Design

Rohitha · Sudheera · Renuka · Manisha (✉) · K. Devi
Department of Civil Engineering, Vidya Jyothi Institute of Technology (A), Hyderabad, Telangana 500075, India
e-mail: korapalamanisha@gmail.com

K. Devi
e-mail: kamalinidevi1@gmail.com; kamalinidevi_civil@cbit.ac.in

Present Address:
K. Devi
Department of Civil Engineering, Chaitanya Bharathi Institute of Technology (A), Hyderabad, Telangana 500075, India

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Shear Stress Estimation in Compound Channel Using M5 Tree and XGBoost Soft Computing Techniques

Neil Tripathi[1], Shashank Shekhar Sandilya [2], Bhabani Shankar Das[3], Kamalini Devi[4], Jnana Ranjan Khuntia[4]
[1]B.Tech. Student, Department of Civil Engineering, National Institute of Technology Patna, Patna, India– 800005
[2]Ph.D. Research Scholar, Department of Civil Engineering, National Institute of Technology Patna, Patna, India– 800005
[3]Assistant Professor, Department of Civil Engineering, National Institute of Technology Patna, Patna, India –800005
[4]Assistant Professor, Department of Civil Engineering, Chaitanya Bharathi Institute of Technology, Hyderabad, India
*neiltripathi1862002@gmail.com

Abstract

Natural rivers have a typical cross-section of compound channels having a main channel and one or two flood plains. Prismatic compound channels maintain uniform water levels, while non-prismatic compound channel exhibits non-uniform and complex flow pattern. Shear stress is generated at the interface of the main channel and flood plain due to momentum transfer. The boundary shear stress distribution cannot be determined easily as they depend upon the velocity field, the shape of the cross-section, and the boundary roughness. This study attempts to develop a model to predict the shear stress in the non-prismatic compound channel using two machine learning (ML) techniques (1) M5 tree and (2) extreme gradient boosting (XGBoost) by considering the impact of several geometric, flow, and roughness parameters such as width ratio, relative flow depth, flow aspect ratio, and bed slope. M5 tree provides significant benefit by presenting transparent formulas that yield a deeper understanding of the derived equations. XGBoost are powerful gradient-boosting algorithms known for their ability to handle structured data. The models are constructed based on several correlated physical channel characteristic variables to predict the shear stress. Predicted shear stress of both M5 tree and XGBoost models has been found satisfactorily with the coefficient of determination (R2) value greater than 0.85 and mean absolute percentage error (MAPE) less than 12 % for training and testing datasets. However, XGBoost model prediction accuracy is better compared to the M5 tree model in predicting shear stress at different sections of non-prismatic compound channels.

Keywords: Prismatic compound channels, non-prismatic compound channel, Main channel, Flood plain, M5 tree, XGBoost

Hydrodynamic Analysis of Raceway Pond using LES Turbulence model

Sweety Rajput[1], B. S. Das[2], Anil Kumar Sharma[2], Jnana Ranjan Khuntia[3], Kamalini Devi[3]

[1]Ph.D. Scholar, Department of Civil Engineering, National Institute of Technology, Patna, Bihar, .800005, India

[2] Assistant Professor, Department of Civil Engineering, National Institute of Technology, Patna, Bihar,800005, India

[3]Assistant Professor, Dept. of Civil Engineering, Chaitanya Bharathi Institute of Technology, Hyderabad-500075, India

[3]Assistant Professor, Dept. of Civil Engineering, Chaitanya Bharathi Institute of Technology, Hyderabad-500075, India

*sweetyrajput113@gmail.com

Abstract

The open-closed looped raceway pond is one of the best energy-saving options that can meet several requirements like; energy and nutritional reclamation, wastewater treatment, and biomass cultivation for biofuel production. At present raceway pond (RP) is widely used for producing biofuel using microalgae as feedstock. The wide use of this technique is because of its low maintenance and construction cost, and its simplicity in operation. Therefore, the hydrodynamic study of RP can be helpful to increase the productivity of the pond. In past decades computational fluid dynamics (CFD) has gained attention in expressing a wide range of parameters even in multiphase flow with a high degree of accuracy in raceway ponds. Various numerical simulations using ANSYS Fluent have been suggested by many authors in existing RP hydrodynamics. Modelling of RP is a cost-effective way to determine its performance under various environmental and physical conditions. The present study aims to use the large eddy simulation (LES) turbulence model to understand the hydrodynamic behaviour of raceway ponds using ANSYS-FLUENT software. The study is performed by taking three different aspect ratios (10, 15, and 20) with constant inlet velocity of flow to understand the performance of the raceway pond. The LES turbulence model is used to determine the effect of velocity and pressure on the performance of RP by varying the geometry of RP. The paddlewheel is used for the mixing mechanism in the raceway pond. Hence the modelling also understands the hydrodynamic behaviour of the raceway pond by varying its position with constant rotation speed.

Keywords: Raceway Pond, ANSYS Fluent, Hydrodynamic, LES, CFD.

CFD Simulation of Non-Prismatic Compound Channels using k-ε and k-ω Turbulence Models

Khuntia J. R.[1*], Devi K.[1], Sahoo S.[2], Das B. S.[3], Khatua, K. K.[4]
[1]Assistant Professor, Department of Civil Engineering, Chaitanya Bharathi Institute of Technology (A), Hyderabad, 500075, India
[2]Ph.D. Scholar, Department of Civil Engineering, National Institute of Technology Rourkela, 769008, India
[3]Assistant Professor, Department of Civil Engineering, National Institute of Technology Patna, 800005, India
[4]Professor, Department of Civil Engineering, National Institute of Technology Rourkela, 769008, India
*jnanaranjan444@gmail.com

Abstract

The discharge estimation in rivers is crucial in implementing flood management techniques and essential flood defence and drainage systems. During the normal season, water flows solely in the main channel, but during a flood, the water overflows its banks and spills into the floodplains, resulting in devastating consequences and loss of livelihood. During the flood, the rivers are composed of a main channel and floodplains, collectively referred to as a compound channel. Computing the discharge is a challenging task in non-prismatic compound channels where the floodplains are either converging or diverging in the longitudinal direction. In compound channels, momentum transfer takes place at the interface of the main channel and floodplain due to the difference in flow velocity in the subsections. Due to this reason, the flow behaviour becomes very complex in a non-prismatic compound channel. Among many flow parameters, velocity distribution, bed shear stress and secondary currents are three essential properties affecting the conveyance capacity of a channel. However, due to the complexity of the methodology, very few attempts have been made by previous researchers to compute the flow properties for non-prismatic compound channels by using numerical methods. So, by accounting for those challenges, the present study aims to simulate the flow properties for non-prismatic compound channels using subgroups of *k*-ε and k-ω models. The computational fluid dynamics (CFD) simulations are performed using the ANSYS-Fluent software package. Four different models, i.e., standard *k*-ε, RNG *k*-ε, standard k-ω and SST k-ω are used to simulate the both diverging and converging non- prismatic compound channel. The velocity profiles and turbulent kinetic energy are analysed at three different locations along the longitudinal direction of channel and four places across the channel. The present SST k-ω model has produced satisfactory results, as compared to the other three turbulence models. This study will be helpful to hydraulic engineers and researchers working on compound channels.

Keywords: Computational fluid dynamics, Non-Prismatic Compound Channel, Turbulence model, ANSYS, *k*-ε model, k-ω model.

CFD Simulation of Confluence of Flow using Different Turbulence Models

S. S. Sandilya[1*], B. S. Das[1], K. Devi[2], J. R. Khuntia[2] and M. P. Mohanty[3]
[1] Ph.D. Research Scholar, Department of Civil Engineering, National Institute of Technology Patna, Patna, India– 800005
[1]Assistant Professor, Department of Civil Engineering, National Institute of Technology Patna, Patna, India – 800005
[2]Assistant Professor, Department of Civil Engineering, Chaitanya Bharathi Institute of Technology, Hyderabad, India
[2]Assistant Professor, Department of Civil Engineering, Chaitanya Bharathi Institute of Technology, Hyderabad, India
[3]Assistant Professor, Department of Water Resources Development and Management, IIT Roorkee, Roorkee, India
*sss.nitp@gmail.com

Abstract

Confluences are often observed in natural and artificial channels. The hydrodynamics of open channel confluences are highly complex due to the development of flow separation, mixing, and secondary currents. Numerical modeling of flows is an important tool used for understanding the behavior of complex flow patterns near the confluence. When the construction of physical models is not economically feasible, numerical models are used to directly evaluate and predict the performance. In the last three decades, a large variety of numerical methods and turbulence models have been developed in order to represent the enormous range of flows existing in nature or in industry. This study attempts to address this issue through numerical simulation of the flow behavior in an open channel confluence in OpenFOAM. A three-dimensional numerical model is set up to evaluate the accuracy of different turbulence models for reproducing the flow characteristics of a 90º open channel confluence, which consists of a common and simple geometry. The flow behavior is simulated by the finite volume method (FVM). The Reynolds-averaged Navier– Stokes equation system was utilized as the governing equations and three different turbulence models were employed in this study the standard k-ε model, the realizable k–ε model, and k-ω. The accuracy of simulation results from three different turbulence models (the standard k-ε model, the realizable k–ε model, and k-ω) has been evaluated by comparing velocity fields. The water surface was treated by a rigid lid approach. The general flow behavior generated by the numerical models was in good agreement with the experimental results, regardless of the rigid lid approach's natural inability to model the free surface. However, none of the turbulence models could reproduce properly the secondary current or the helicoidal current downstream of the junction. There is no appreciable difference has been found in the performance of the standard k-ε model, the realizable k–ε model, and the k-ω model. However, Statical analysis recommends that the realizable k– Epsilon turbulence model is more reliable in predicting complex flow geometries such as in the case of the confluence of flow than the k-Omega turbulence model and the standard k- Epsilon turbulence model.

Keywords: OpenFOAM, FVM, Realizable k–ε model, Standard k-ε model, k-ω, Rigid lid approach

Study of Drought Severity and Agricultural Water Demand near Godavari Basin

Vikesh, P[1*], Harshitha, S[2],Sharanya, P[3], Devi, K[4], Khuntia, J.R[5], Bhabani Shankar Das[6]
[1,2,3]UG Student, Department of Civil Engineering, Vidya Jyothi Institute of Technology, Aziz Nagar Gate, C.B Post, Hyderabad, India – 500075
[4,5]Assistant Professor, Dept. of Civil Engineering, Chaitanya Bharathi Institute of Technology, Hyderabad-500075, INDIA
[6]Assistant Professor, Dept. of Civil Engineering, National Institute of Technology, Patna, INDIA
*pulivikeshyadav@gmail.com

Abstract

For crop management and agricultural water demand in the Godavari River basin, the largest river system in peninsular India. In the present research, Polavaram gauge station of Godavari River in Andhra Pradesh, specifically in Polavaram village, Eluru district is considered as study area. The study area is accurately extracted using remote sensing technology with Google Earth Pro and ArcGIS software, enabling precise spatial mapping and visualization. The primary objective is to investigate the prevalence of drought and flood events within the Godavari basin, crucial for effective water resource management and agricultural planning. The study incorporates an index value (Standardized Precipitation Evapotranspiration Index (SPEI) of the river Godavari’s cross-section and sediment data, collected from the central water commission (CWC) in Hyderabad. Different types of droughts, including meteorological, agricultural, hydrological, and ecological are analysed to assess meteorological drought impact, hydrological droughts impact the researchers utilize the Standardized Precipitation Evapotranspiration Index (SPEI) over various time periods (1 month,3 months, 6 months, 9 months and 12 months). The variations in the cross section of the Godavari River across different time scales are analysed. Additionally, hydrological drought is examined using the Standardized Water-level Index (SWI). These indices are served as essential input for developing the model, monitored at different time scales. Furthermore, the project investigates how changes in the cross-sectional area impact the discharge of the river. Conveyance estimation system (CES) is used to calculate flow rate of given cross-section. Finally, the present study provides valuable insights into the flow dynamics of the Godavari River, crucial for effective agricultural water demand management and sustainable crop practices in the region.

Keywords: Standardized Precipitation Evapotranspiration index (SPEI), Standardized water-level (SWI), conveyance estimation system (CES), Google earth pro, ArcGIS software.

Modelling of Rainfall Using Regression Analysis and Soft Computing Technique

Rahul, K[1], Jayasree, A[2], Sravan, M[3], Khuntia, J. R[4], Devi, K[5], Das, B. S[6]
[1,2,3]UG Student, Department of Civil Engineering, Vidya Jyothi Institute of Technology, Aziz Nagar Gate, C.B Post, Hyderabad, India – 500075.
[4,5]Assistant Professor, Dept. of Civil Engineering, Chaitanya Bharathi Institute of Technology, Hyderabad- 500075, INDIA
[6]Assistant Professor, Dept. of Civil Engineering, National Institute of Technology, Patna, 800005, INDIA
*kandakatlarahul18@gmail.com

Abstract

India is a country highly dependent on rainfall for its various activities which include agriculture, businesses and other direct metrics which directly affect the economy. The rainfall prediction does not only assist in analysing the changing patterns of rainfall, but it will also help in organizing the precautionary measures in case of disaster and its management. The changing patterns of rainfall are associated much with the global warming; that is increasing of the earth's temperature due to increase of Chlorofluorocarbons emitting from the refrigerators, air conditioners, deodorants, printers etc. causing melting of the snow caps, altered weather patterns have become significant part of everyone's life. The rainfall for a particular location is more dependent on the different factors like, relative humidity, specific humidity, temperature, wind speed, wind direction surface pressure, evaporation, transpiration, percolation, runoff, ocean currents, population, El Nino & La Nina etc. Rainfall forecasting or predicting is very important because heavy and irregular rainfall can have many impacts like destruction of crops and farms, damage of property, so a better forecasting or predicting model is essential for an early warning that can minimize risks to life and property and also managing the agricultural farms in better way. This project aims to create a distinctive and effective mathematical model and machine learning system for rainfall prediction. In this study, various rainfall metrics from Osman Sagar catchment of Gandipet mandal, Telangana are tested in order to measure the model's effectiveness and perseverance. This study focuses on development of mathematical model by using multi linear regression analysis (MLRA) and artificial neural network (ANN) models. The data learning is performed using a hybrid and back propagation network approach. The relationship between the dependent and independent parameters of rainfall have been demonstrated graphically. The MLRA and ANN models used in this study are trained and tested to achieve the sustainable results. The model's accuracy is checked by comparing the model's monthly rainfall forecasts with actual data after training and testing. The study's findings show that the model is effective in forecasting monthly rainfall data with the specific parameters and statistical error analysis has been performed to evaluate the strength of the models. Finally, the developed model has validated for the year 2022 and the future prediction has been done for the year 2025 and 2030.

Keywords: Rainfall prediction; Machine Learning; Artificial Neural networks; Multi Linear Regression; Error analysis.

Modelling of Scour Depth Using Multivariable Regression Analysis

Pragathi.C[1], Gouthami.K[2], Mahendar.G[3], Devi.K[4], Khuntia.J.R.[5]and Pallavi Badry[6]
[1]Student, Department of Civil Engineering, Vidya Jyothi Institute of Technology, Hyderabad-500075, India
[2]Student, Department of Civil Engineering, Vidya Jyothi Institute of Technology, Hyderabad-500075, India
[3]Student, Department of Civil Engineering, Vidya Jyothi Institute of Technology, Hyderabad500075, India
[4]Assistant Professor, Department of Civil Engineering, Chaitanya Bharathi Institute of Technology, Hyderabad-500075, India
[5]Assistant Professor, Department of Civil Engineering, Chaitanya Bharathi Institute of Technology, Hyderabad-500075, India
[6]Professor, Department of Civil Engineering, Vidya Jyothi Institute of Technology, Hyderabad-500075, India
*pragachilkamarri@gmail.com

Abstract

The lowering of bed levels below the natural levels due to sediment transport is referred to as scour. Scouring is the vital cause of failure in hydraulic structures; thus, it is important to know the extent of scour. Scour takes place due to the localized divergence in sediment transport due to the construction of an obstruction over the existing flow pattern. The study here presents a numerical estimation of the maximum equilibrium scour depth under existing conditions at the site. The various parameters that are affecting the rate of sediment transport are studied by investigating the data sets of previous researchers. The estimation of maximum equilibrium scour depth uses the Adaptive Neuro-Fuzzy Inference System (ANFIS) as a modeling technique. In the present study, various independent parameters such as pier diameter, sediment size, approach flow velocity, approach critical flow velocity, flow depth, Froude number, and the dependent parameter, i.e., equilibrium scour depth, are considered. An equilibrium scour depth model is constructed by making use of ANFIS. For that, 218 training datasets and 57 testing datasets are sorted to establish the ANFIS model from previous studies. A gamma test has been performed on all the input-output pairs to select the best input combinations to prepare an efficient model. The scour depth model is developed using ANFIS with an average MAPE of 17.5 for all data sets.

Keywords: scour, hydraulic structures, independent parameter, ANFIS, equilibrium scour depth, gamma test.

Estimation of Water Borne Soil Loss using Rusle and Gis in Hussainsagar Catchment

Pragna Kasarla[1], Rajesh Katta [1], Ramanarayan Sankriti[1], K Jagannadha Rao[1], Saravanan Subbarayan[2*]
[1] Chaitanya Bharathi Institute of Technology(A), Hyderabad, India
[2] Associate Professor, NIT Tiruchirappalli, India
* ssaravanan@nitt.edu

Abstract

Assessing soil erosion is important for the watershed's sustainable development, which is a global challenge for land-use planners. The environment is still in danger from manmade activities leading to land degradation. Planning and conservation efforts in a watershed benefit from evaluation of soil erosion. Modelling can offer a systematic and quantitative method to calculate soil erosion. In this study, the Revised Universal Soil Loss Equation (RUSLE) soil loss model and Geographic Information Systems (GIS) were used to predict soil loss in the Hussainsagar watershed in south-central India. Remote-sensing (RS) data were used to estimate "RUSLE" model parameters, and "GIS" was incorporated to pin-point erosion hotspots. The results indicate that the northwestern part of the watershed saw the greatest estimated total yearly potential soil loss. To prevent soil erosion in the Hussainsagar watershed, the results can undoubtedly help with the application of soil management and conservation practices. This model considers a number of variables, including the slope-length and gradient index (LS), rainfall and runoff erosivity index (R), soil erodibility index (K), crop cover management component (C), and supporting practice index (P). On a GIS platform, each of these layers was created utilizing various data sources and data preparation techniques. The average yearly soil loss in the watershed is close to 0.5 tons/ha/year, according to the study's findings.

Keywords: RUSLE, GIS, Hussainsagar, watershed, Erosion, Soil Loss

A Study on Flexural Behaviour of Reinforced Concrete with Partial Replacement of Cement with GGBS

Mohammed Adeeb Ahmad
M.E., Student, Chaitanya Bharathi Institute of Technology, Hyderabad, Telangana, India

Dr. N.R. Dakshina Murthy
Associate Professor, Department of Civil Engineering, CBIT, Hyderabad, Telangana, India

Abstract

As the building business continues to grow most rapidly and significantly in developing nations like India, concrete is a key component combination that is most frequently used in this sector. To make that mixture, the main ingredients are cement, fine aggregate, coarse aggregate, and water. To make cement, however, we need raw materials like lime, silica, alumina, and other minerals that must be mined from the earth's interior. This mining activity causes significant disruption to the earth's core and also produces pollution that has a significant negative impact on the environment. As a result, it is important to minimize the use of raw materials and regulate mining activities. daytime setting Therefore, in order to lessen our impact on the environment, we must utilize the waste products that we produce, such as industrial waste, agricultural waste, and so on. For example, waste products from the cement industry, such as ground granulated blast furnace slag (GGBS) silica fume fly ash fiber, can be replaced with waste products from the agricultural sector, such as rice husk. As an alternative to cement, coconut coir, sugarcane bagasse, and other plant materials may be used; however, these alternatives must be tested for feasibility and embeddedness in the cement as well as the qualities of the combination.

Keywords

Ground granulated blast furnace slag (GGBS), reinforced concrete, load-deflection characteristics.

Mechanical Properties of Reinforced Concrete with Partial Replacement of Cement with GGBS

M. Arun Sai Kumar
M.E., Student, Chaitanya Bharathi Institute of Technology, Hyderabad, Telangana, India

Dr. N.R. Dakshina Murthy
Associate Professor, Department of Civil Engineering, CBIT, Hyderabad, Telangana, India

Abstract

The present work concerns the mechanical characteristics of reinforced concrete that has had some of its cement replaced with ground granulated blast furnace slag (GGBS). Because it is an industrial waste product, it is an inexpensive alternative to cement. Parallel to ground granulated blast furnace slag (GGBS), there are various alternatives to cement including fly ash, rice husk ash, nano silica, basalt fiber, geopolymers, palm oil fuel ash, and so on... these waste products can substitute cement and lower cement production and its usage. The experimental investigation included cubes, cylinders, prisms, and a beam. Ordinary Portland cement was replaced with 20% GGBS and glenium 3705 was used as a superplasticizer for casting cubes, cylinders, prisms, and a beam. This mixture is already established in the field, but to know its strength and characteristics, tests have been performed in the laboratory. Results for compressive strength, split tensile strength, flexural strength, and load-deflection characteristics were reported as test data. The test findings were compared between concrete mixes with and without ground granulated blast furnace slag (GGBS).

Keywords

Ground granulated blast furnace slag (GGBS), reinforced concrete, load-deflection characteristics.

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Soil Interaction Studies on Plinth Beams

Poluri Venkata Naga Sai Kiran*
Assistant Professor, Kallam Haranadhareddy Institute of Technology, Guntur, Andhra Pradesh, India

K. Siva Kiran
Assistant Professor, Kallam Haranadhareddy Institute of Technology, Guntur, Andhra Pradesh, India

M. Jugal Kishore
Assistant Professor, Kallam Haranadhareddy Institute of Technology, Guntur, Andhra Pradesh, India

C. Ravi Kumar Reddy
Professor, Chaitanya Bharathi Institute of Technology, Hyderabad, Telangana, India

Abstract

Most of the civil engineering structures involve some type of structural element with direct contact with ground. When the external forces such as earthquakes, act on this systems, neither the structural displacements nor the ground displacements, are independent of each other. The process in which the response of the soil influences the motion of the structure and the motion of the structure influences the response of soil is termed as soil structure interaction (SSI). Plinth beam ideology is similar to normal roof beam but the difference is its soil structure interaction which is absent in case of normal beam. Regular structural design practices disregard the soil structure interaction (SSI) effects. The present study considers a plinth beam resting on loose sand having rectangular cross section of length varying from 1m to 10m, width 0.2m and depth varying from 0.2m to 1.0m is modeled and analysed using ANSYS for obtaining numerical solution while conventional analysis (plinth beam without soil contact) is carried out by using STAAD. Pro.

From the analysis results it is observed that, If the depth of the beam increases SF and BM also increase. SF and BM is directly proportional to the flexural rigidity, as flexural rigidity of beam increases SF and BM also increases. The reason for higher soil interaction effect at lower depths of beam is the rigidity of soil plays an important role when compared to structural rigidity as the soil is more rigid compared to structure the soil offers more resistance which reduces the effect of gravity loads. When the structure is made more rigid than soil it offers less resistance to gravity loads hence the interaction effects are reduced. Maximum shear force, bending moment, deflection have been studied from finite element analysis and conventional analysis to establish the SSI effect and the following conclusion have been drawn from the study. As depth increase from 0.2m to 1m increase in shear force is reduced from 80.71% to 4.50% for 10m length of plinth beam due to SSI. As depth increase from 0.2m to 1m increase in bending moment is reduced from 75.58% to 4.37% for length of plinth beam 10m due to SSI. As depth increase from 0.2m to 1m decrease in deflection is reduced from 87.38% to 5% for 10m length of plinth beam due to SSI.

Keywords

Plinth beam, Soil interaction, Deflection, Design forces.

Soft Computing Techniques for the Prediction of Strength for Geopolymer Concrete

Mendu Uday Bhaskar*
Assistant Professor, Malla Reddy Engineering College (A), Maisammaguda, Hyderabad, Telangana, India

M. Jugal Kishore
Assistant Professor, Kallam Haranadhareddy Institute of Technology, Guntur, Andhra Pradesh, India

K. Siva Kiran
Assistant Professor, Kallam Haranadhareddy Institute of Technology, Guntur, Andhra Pradesh, India

C. Ravi Kumar Reddy
Professor, Chaitanya Bharathi Institute of Technology, Hyderabad, Telangana, India

Abstract

The destructive and non-destructive tests were performed on totally 81 laboratory- made concrete cubes. Regression analysis was carried out. Simple relationships were determined and correlated between non-destructive testing (NDT) named as Schmidt rebound hammer test and concrete destructive compression test. The Schmidt rebound hammer is principally a surface hardness tester with an apparent theoretical relationship between the strength of concrete and the rebound number of the hammer. Schmidt hammer was applied in both vertical and horizontal positions. The standard concrete cubes were prepared with various mix proportions that yielded standard cubes crushing strengths (f cu) within a range of 15 to 40 MPa.

Keywords

Regression analysis, Destructive tests, Rebound Number, Schmidt hammer.

Development of Innovative Flexible Pavement Design Utilizing Cement-Treated Base and Its Impact on Cost

M. Jugal Kishore*
Assistant Professor, Kallam Haranadhareddy Institute of Technology, Guntur, Andhra Pradesh, India

Poluri Venkata Naga Sai Kiran
Assistant Professor, Kallam Haranadhareddy Institute of Technology, Guntur, Andhra Pradesh, India

Gogireddy Somi Reddy
Assistant Professor, Kallam Haranadhareddy Institute of Technology, Guntur, Andhra Pradesh, India

C. Ravi Kumar Reddy
Professor, Chaitanya Bharathi Institute of Technology, Hyderabad, Telangana, India

Abstract

The Pavement refers to the long-lasting surface material installed in areas intended for supporting both vehicular and pedestrian traffic, such as roads and walkways. There are two primary types of pavements: flexible pavements and rigid pavements. In the case of flexible pavements, they consist of three distinct layers: bitumen, granular, and subgrade layers. Each of these layers bears the loads from the layer above, distributes them evenly, and then transfers them to the subsequent layer beneath. The name 'flexible pavements' derives from the fact that the entire pavement structure deflects or flexes when subjected to loading. Non-conventional pavements are those that incorporate alternative materials. By introducing cement into the wet mix macadam (WMM) layer, the pavement's strength is enhanced, and one of the bituminous layers, known as dry bituminous macadam (DBM), is eliminated. Consequently, this modification reduces the overall cost of the pavement by approximately 40%. This project entails designing both a conventional pavement and a non-conventional pavement using the IIT-PAVE software. A comparative analysis is conducted between the two pavement types, examining their designs and associated costs.

Keywords

Non-conventional Pavements, Wet Mix Macadam (WMM), Dry Bituminous Macadam (DBM), Cement-modified Pavement, Cost-effective Pavement, IIT-PAVE Software.

Corrosion Characteristics of Steel Reinforcement in Geopolymer Concrete Subjected to Saline Environment

T. Muralidhara Rao
Professor, Department of Civil Engineering, CVR College of Engineering, Hyderabad, Telangana, India

Chava Venkatesh
Assistant Professor, Department of Civil Engineering, CVR College of Engineering, Hyderabad, Telangana, India

Chereddy Sonali Sri Durga
Assistant Professor, Department of Civil Engineering, CVR College of Engineering, Hyderabad, Telangana, India

Jagadeesh Bommisetty
Assistant Professor, Department of Civil Engineering, CVR College of Engineering, Hyderabad, Telangana, India

Ravi Kumar Reddy C
Professor, Department of Civil Engineering, Chaitanya Bharathi Institute of Technology, Hyderabad, Telangana, India

Abstract

Corrosion of steel reinforcement is one of the major serviceability problems especially when the reinforcement is exposed to the chlorides either contributed from the concrete ingredients or penetrated from the surrounding chloride-bearing environment. Using accelerated corrosion technique, it is proposed to study the influence of corrosion inhibitors like calcium nitrites (0%, 2%, 4%, 6%) and sodium nitrites (0%, 2%, 4%, 6%) on the Fe550 grade steel reinforcement corrosion of M20 grade Geopolymer concrete cylindrical specimens prepared using 3M and 5M alkali activators. In this accelerated corrosion technique, Geopolymer concrete cylinders with rebar induced are placed in the 5% NaCl solution and the corrosion time and corrosion current required for the corrosion of steel reinforcement bars was calculated by supplying a constant voltage of 12volts. Three cylindrical specimens of 200mm diameter and 100mm height are cast in each percentage of corrosion inhibitors and the corrosion characteristics like mass loss and rate of corrosion of steel reinforcement were calculated. 200mm length and 10mm diameter steel reinforcement bar was used in the Geopolymer concrete cylindrical specimens. 4% of calcium nitrite and 4% of sodium nitrite with 3M and 5M alkali activators were found to be optimum with less mass loss and rate of corrosion. The mass loss and rate of corrosion of 3M alkali activator Geopolymer concrete mix were less compared to that of 5M alkali activator geopolymer concrete.

Keywords

Accelerated Corrosion Apparatus, Corrosion Inhibitor Alkali Activators, Corrosion Rate, Mass Loss, Geopolymer Concrete.

Corrosion Characteristics of Rebar in Fly Ash-GGBFS Synthesised Alkali Activated Concrete

T.Muralidhara Rao*
Department of Civil Engineering, CVR College of Engineering, Hyderabad, India

Chava Venkatesh
Department of Civil Engineering, CVR College of Engineering, Hyderabad, India

Chereddy Sonali Sri Durga
Department of Civil Engineering, CVR College of Engineering, Hyderabad, India

Jagadeesh Bommisetty
Department of Civil Engineering, CVR College of Engineering, Hyderabad, India

Ravi Kumar Reddy C
Department of Civil Engineering, Chaitanya Bharathi Institute of Technology, Hyderabad, India

Abstract

Corrosion of steel bars is one of the major serviceability problems especially when the reinforcement bars are exposed to chlorides either from the concrete ingredients or the surrounding chloride environment. Using accelerated corrosion technique, it is proposed to study the influence of anodic corrosion inhibitors like calcium nitrites (0%, 2%, 4%, 6%) and sodium nitrites (0%, 2%, 4%, 6%) on the Fe550 grade steel reinforcement corrosion of M20 grade Geopolymer concrete (70%FA+30%GGBFS) cylindrical specimens prepared using 3M and 5M alkali activators. In this accelerated corrosion technique, Geopolymer concrete cylinders with rebar inserted are placed in the 5% NaCl solution and the corrosion time and corrosion current required for the corrosion of steel reinforcement bars was calculated by supplying a constant voltage of 12volts. Three cylindrical specimens of 200mm diameter and 100mm height are cast in each percentage of corrosion inhibitors and the corrosion characteristics like Corrosion rate, mass loss, Corrosion density, Corrosion current, Corrosion time of steel reinforcement were calculated. 200mm length and 10mm diameter steel reinforcement bar was used in the Geopolymer concrete cylindrical specimens. 4% of Calcium nitrite ($Ca(No_2)_2$) and 4% of Sodium nitrite ($NaNo_2$) with 3M and 5M alkali activators were found to be optimum with less mass loss and rate of corrosion. The mass loss and rate of corrosion of 3M alkali activator Geopolymer concrete mix were less compared to that of 5M alkali activator geopolymer concrete.

Keywords

Accelerated Corrosion, Corrosion Inhibitors, Alkali Activators, Corrosion Rate, Mass Loss, Geopolymer Concrete, Serviceability, Sustainable environment.

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Abstract

India has an urban population that makes up more than 34% of the country's total population. Water, petroleum, oil products, and other liquids are kept in storage tanks and overhead tanks. These tanks have been employed in several different fields, including agriculture, the food industry, paper mills, firefighting, and water distribution. It is well

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N. B. S. Priyadarshini, M. Ashritha, Kamalini Devi & A. Obulesh

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Abstract

In the existing work, cost optimization for an R/C structure system was performed by using machine learning. In fetch optimization, the aspects of the shear wall were contemplated as design variables, and the objective was to find the optimal shear wall aspects that keep down the overall cost of the material. The limitations of the structural

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(ATIPC 2022)

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Abstract

India's Stake in Emerging Technology - A Review

Sugandha Singh
Department of Computer Science and Engineering
SGT University
Gurugram, India
sugandha77.cse@gmail.com

China Ramu S
Department of Computer Science and Engineering
Chaitanya Bharathi Institute of Technology
Hyderabad, India
chinaramu_cse@cbit.ac.in

Ruchika Lalit
University School of Automation and Robotics
GGSIPU, East Campus
New Delhi, India
ruchikalalit@gmail.com

***Abstract*—Emerging technologies of today are altering the way we think about the built environment. In the meantime, many technologies have undergone revolutionary changes, and India, an expanding nation, offers opportunities for development in several new areas. The goal of the study is to show how organizations need to adapt their perspective and create new strategies for emerging technologies such as artificial intelligence (AI), machine learning (ML), big data, quantum, and space exploration in light of the swift advancements in technology. This paper presents that although India has come across a lot of advancements in this era of emerging technology, certain challenges have been faced in aspects like adapting, feasibility, and approval which brought many changes across the country, which in turn is impacting the pace to transform the country towards Industry 4.0 and Industry 5.0. Therefore a study is presented to understand the impact of emerging technologies for countries coming up as Industry 4.0 and Industry 5.0. This paper emphasizes on for India's initiatives for emerging technologies to come up as VIKSIT BHARAT @2047.**

Keywords— Big Data, Quantum computing, Artificial Intelligence, Hypersonic platforms, Fabrication, Industry 4.0 and Industry 5.0.

I. Introduction

In the next 20 years, emerging technologies like Big Data and Advanced Analysis, Artificial Intelligence, Robotics, Hypersonic Platforms, Space Systems, Quantum Technology, and Advanced Materials and Manufacturing will disrupt and revolutionize future conflicts. Countries like the USA and China are investing heavily in these technologies. Presently, India lacks self-reliance even in core technology areas and supply chains which is a prerequisite to excel in emerging technologies. Though India has initiated certain steps in this direction, however, various challenges need to be overcome to make tangible gains and eventually attain leadership status in these emerging technologies. The extremely intelligent linked systems of Industry 4.0 produce a fully digital value chain. It primarily relies on cyber-physical production systems, which combine data, IT, communications, and physical components. These systems turn conventional plants into intelligent factories. The goal here is to have machines communicating with other machines, products, and information processing and distribution in real time, which will have a significant impact on the industrial ecosystem as a whole. [11, 13]

Human conflict has been in existence since the dawn of civilization, however, domains and ways of prosecution of conflicts have been changing continuously. With the advent of aircraft and missile technologies, air medium has become the third domain of prosecution of warfare in addition to already existing land and sea domains. With the Launch of satellites, air medium has been extended to space. Dependency on networks and information in the prosecution of conflicts created cyberspace as the fourth domain. It is amply clear that the advancement in technology is one of the prime drivers of transforming conflicts. One important metric for assessing a nation's performance in the digital era is the Networked Readiness Index. [14, 15] Whether a nation has the drivers needed for digital technologies to reach their full potential and whether these innovations are substantially affecting the economy and society are the determining factors. Since innovation is becoming more and more dependent on digital technology and the new economic models they enable, the digital revolution may alter the nature of innovation. Any country that invests in crucial technologies and achieves leadership status not only in these technologies but also in the corresponding supply chains will emerge as an influential player in the world order. Therefore, India being an aspiring state to play an active role in world affairs cannot afford to overlook the areas of crucial technologies and materials that are likely to impact future conflicts. Notably, India ranked 61 in 2013 on the Network Readiness Index. India came in at number 91 out of 139 nations in 2016. India ranked 91st, behind Malaysia (31), China (59), and Bangladesh (112) but ahead of Pakistan (110) and Sri Lanka (63). For the second consecutive year, Singapore topped the standings. The United States was ranked fifth. In 2023 India again uplifted back to rank 61 whereas the United States of America hiked to rank 1 and Singapore came on rank 2. [16]

The World Economic Forum (WEF) report makes it abundantly evident that there is a wide disparity between industrialized and developing countries due to a variety of variables. It claims that developed and developing countries are now split into two categories by the digital economy. Why is Industry 4.0 important to India? Industry 4.0 makes it possible to reduce inefficient procedures and behaviors and maximize the utilization of energy and other inputs. This is accomplished by gathering data, analyzing it, and applying the results to enhance the efficiency of industries, systems, and

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A Survey on Voice Cloning and Automated Video Dubbing Systems

S. China Ramu
Professor, Department of CSE
Chaitanya Bharathi Institute of Technology
Telangana, India
chinaramu@gmail.com

Dhruv Saxena
Student, Department of CSE
Chaitanya Bharathi Institute of Technology
Telangana, India
dhruv162002@gmail.com

Vikram Mali
Student, Department of CSE
Chaitanya Bharathi Institute of Technology
Telangana, India
vikram595959@gmail.com

***Abstract*—In the context of today's interconnected world, where multilingual interactions are commonplace, the need for effective cross-language communication solutions is paramount. This survey explores innovative approaches to multilingual video dubbing, focusing on the integration of voice cloning and neural machine translation techniques for translating and dubbing videos across different languages while maintaining the authenticity of the original speaker's voice and ensuring seamless lip movement with the source video. Various advanced techniques, including voice cloning, speech emotion recognition, speech-to-lip synchronization, and neural machine translation, are employed in the examined literature. These techniques collectively aim to identify the source language, translate the content, and synthesize the speaker's voice in the target language that is synchronised with the source video. This survey also delves into the challenges associated with cross-language voice cloning and linguistic translation, exploring the collaborative potential of these technologies within the realm of video dubbing. The overarching goal is to contribute to the accessibility of multimedia content on a global scale, enabling viewers to enjoy videos in their preferred language without compromising the identity of the original speaker. Through comparative analyses of various algorithms, the effectiveness of these approaches in achieving high-quality, linguistically accurate, and emotionally resonant multilingual video dubbing is analyzed.**

***Index Terms*—Multilingual video dubbing, voice cloning, neural machine translation, speech emotion recognition, synchronizing speech with lips, cross-language voice synthesis.**

I. Introduction

In the ever-expanding global landscape of communication, transcending linguistic barriers has become a critical necessity. Video content, a potent medium for information distribution and cultural exchange, faces a considerable obstacle in the form of language diversity, hindering its widespread global distribution. The historical narrative in this field spans from the inception of video dubbing challenges to present-day efforts to bridge linguistic gaps. The need for such systems has grown exponentially with the global expansion of video content, prompting researchers to explore innovative solutions. From early attempts at lip syncing to recent breakthroughs in neural voice cloning, each development has contributed to the evolution of the field. Among these, multilingual video dubbing emerges as a pivotal solution, facilitating seamless translation while preserving the authenticity of the original speaker's voice[1][2].

This survey delves into the challenges and advancements in multilingual video dubbing, exploring a system designed to address these issues. Rooted in a comprehensive review of recent literature, our survey draws inspiration from groundbreaking work in pose-aware animated facial landmarks[1]. Novel data augmentation techniques, utilizing LSTM-based networks to decouple lip, jaw, and head motions, enhance the system's robustness[1]. Additionally, the integration of a unique neural fusion architecture, employing a unit concatenation method for improved speaker similarity and speech quality, forms the foundation of the audio synthesis system[3]. Insights from a CNN and ResNet based speaker extraction algorithm, incorporating visual cues and speech-lip synchronization, contribute to the adaptability in noisy environments with multiple speakers[2]. Exploration into cross-speaker emotion transfer and control for speech synthesis, disentangling prosody and timbre in emotional characteristics[4], informs our approach to maintaining emotional authenticity during translation.

The primary objective of this survey is to examine innovative approaches that seamlessly integrate advanced voice cloning and neural machine translation techniques. Drawing from methods such as facial landmark animation[1], lip syncing[5], and neural fusion for voice cloning[3], this survey aspires to analyze the landscape of real-time multilingual video dubbing with a focus on precision and emotional resonance[4]. The exploration opens new possibilities for real-time video dubbing across diverse domains, such as sports commentary, informative and entertainment videos, and news channels. Notably, the proposed solutions distinguish themselves by preserving the speaker's voice characteristics and offering an authentic viewing experience with support for Indian languages. The system processes input videos, pre-recorded or live, through concurrent tasks, including language identification[2], transcription and translation[6], lip synchronization[5][7], and real-time voice cloning[8].

The journey from early attempts at overcoming language barriers in video content to contemporary developments in real-time multilingual video dubbing illustrates the persistent efforts of researchers to enhance global communication and accessibility. This survey culminates with a clear research question, directing attention to the challenges and innova-

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Precision farming practices with data-driven analysis and machine learning-based crop and fertiliser recommendation system

G. Vijender Reddy[1*], M. Venkata Krishna Reddy[2], K. Spandana[2], Yerragudipadu Subbarayudu[3], Ali Albawi[4], Rakesh Chandrashekar[5], Atul Singla[6] and Praveen[7]

[1] Department of Information Technology, GRIET, Hyderabad, Telangana, India.

[2] Department of Computer Science and Engineering, Chaitanya Bharathi Institute of Technology (A),

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A Reversible Approach for Hiding Data in Digital Media using Gray-Scale Images

Ravi Uyyala
Department of CSE
CBIT, Hyderabad
uyyala.ravi@gmail.com

Y Ramadevi
Department of AI & ML
CBIT, Hyderabad
yramadevi_cseaiml@cbit.ac.in

Raman Dugyala
Department of CSE
CBIT, Hyderabad
ramand_cse@cbit.ac.in

***Abstract*—Inevitably, Secret data is communicated through digital media using traditional data-concealing techniques. The known approaches like data hiding in the literature cannot restore the original media. Only the Reversible Data Hiding (RDH) method allows for the simultaneous recovery of the original storage media and the concealed information. In cases where the original media must be preserved, RDH can be employed. As a result, RDH is employed in numerous contexts where the original medium is required alongside the concealed information. To conceal sensitive information in an initial image pixel, Difference Expansion (DE) based RDH analyzes the difference between surrounding pixels. The secret information in the HbS-based technique is inserted into the histogram's peak and zero bins. To embed the secret data into the original medium, the prediction error (PE) is enlarged in the PEE-based approach. RDH's primary goal is to insert additional data with little loss of quality. In this study, we first investigate three methods for hiding information within the primary cover image and then retrieving it. Later, we'll look at how the PSNR of these three systems compares to one another. Finally, the research has drawn a conclusion based on the three methods for incorporating data with minimal loss of quality.**

***Index Terms*—Reversible data hiding, Difference Expansion (DE), Prediction Error Expansion (PeE), and Histogram Bin Shifting (HbS).**

I. Introduction

With the rapid development of digital media (i.e., Video, Audio, and Image) and distributed environment, a lot of information is shared across the network systems. In most of the cases, this information contains secret messages. Thus, the protection and security of this information is an urgent measure. The art of data concealment is known as data hiding, in which the inserted data cannot be detected. In data hiding techniques, digital images are often used for transferring the secret message [1]. In data hiding methods, the original cover image is not guaranteed to be recoverable. The RDH is a data-hiding without loss method because the primary image and the hidden message can both be retrieved. The spatial domain and transform domain can be used to embed the data loss-lessly. The spatial domain gives more redundancy to the image than the transform domain. Thus, the spatial domain is more suitable for inserting data with less distortion. The different classes of RDH in the spatial domain are 1 DE 2 HbS 3 PeE.

In the DE method, the watermark is incorporated by increasing the difference between neighboring pixels. Another technique that was designed specifically for color images uses difference expansion to produce a vector of pixel values that are specific to each color channel [2]. Instead of using a physical location map, the work modifies the bins of the expandable difference histogram [3]. A generic paradigm for efficient HbS is proposed in [4] as well. HbS is the usual name for this method. More popularity due to achieving less embedding distortion.

The watermark in PeE-based techniques is the inflated difference between the actual and anticipated pixel values [5]. The performance of PeE depends on the sharpness of the PE histogram (PEH) distribution near fewer error values. Extensive work has been carried out in order to find new approaches for predicting a pixel value with minimum PE.

The method used to produce interpolation errors and expand them to include the watermark is described in [6]. The central pixel value can be predicted using bilinear interpolation with four diagonal neighbors. Delaunay triangulation vertices are used to make predictions using a method called scattered interpolation, as suggested in [6]. Another variety of the RDH technique is one that is predicated on PeE and makes use of a predetermined collection of standard pixels. The first batch of standard pixels is utilized in the process of making local adjustments to the total number of standard pixels. There are many other standard pixels-based forecasts suggested in [6] and [7]. At first, the methods utilized for prediction were profoundly affected by the study of image coding. The MED is used by the PeE-based RDH described in [5]. When trying to anticipate a pixel, the GAP made use of both horizontal and vertical gradients, as well as the strengths of each [5]. In addition, the gradient predictors are utilized in the RDH methodology in order to forecast a pixel value [8], [9], [10] and [11]. A RDH based on various prediction and Embedding schemes also mentioned in [12] and [13]. This RDH can also be used for various purposes in different sectors like cyber forensics and other related applications [14].

Pixel Value Ordering (PVO) based approaches have recently emerged as a sub-genre of PeE. Better performance can be attained with reduced capacity by adapting PVO-based approaches. A PVO-based technique makes an embedded prediction for a pixel based on the nearest gray level in the vicinity inside a block. Li et al [15] presented the first PVO-based approach, in which a data bit is hidden by altering the maximum and/or minimum intensity pixels. By taking into

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Prediction Based Reversible Data Hiding for Gray-Scale Images

Ravi Uyyala
Department of Computer Science and Engineering
Chaitanya Bharathi Institute of Technology (CBIT),
Gandipet, Hyderabad, India
uyyala.ravi@gmail.com

Sriramulu Bojjagani
Department of Computer Science and Engineering
School of Engineering and Applied Sciences, SRM-AP, Amaravathi
Andhra Pradesh, India
sriramulubojjagani@gmail.com

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***Abstract*—Predicting the pixel is crucial in prediction error expansion (PEE) based reversible data hiding (RDH). There are a number of methods for predicting pixels that can be found in research papers. The gradients are used to make a prediction about the current pixel. Gradients in the image can be used to make forecasts about the current pixel, and this has been the subject of extensive study. In this work, we suggest a three-by-three grid of surrounding pixels as a basis for prediction. Later, the histogram bin shifting technique was implemented to integrate more information with less distortion. In order to include more information, the suggested technique makes adaptive changes to the histogram based on local complexity. The experimental analysis demonstrates that When compared to the other, the proposed method is superior.**

***Index Terms*—Reversible data hiding, Gradient Expansions, Bin-shifting in an adaptive histogram.**

I. Introduction

The goal of the almost 20-year-old RDH approach is to achieve secret dialogue that doesn't sacrifice appearance. The earliest and most comprehensive research advancements have been made on RDH techniques in the plain-text arena [1].

Inverting an embedded image is possible and retrieve the main information is the primary feature that sets RDH apart from other solutions. By introducing a change to the pixel values that may be undone, additional data is appended to the primary data set. For the reason that the change can be undone, the primary data may be reclaimed from embedded information while at the same time retrieved the secret information. This is made possible by the fact that the transformation can be undone. Therefore, the values of all of the pixels in the repaired image are about the same as their values in the primary data.

These steps are becoming increasingly effective in a variety of situations where the recovery of the primary data is of the utmost importance. The research available on RDH includes a great number of different approaches [1]. The RDH strategy was initially presented in [2]. Since then, a variety of RDH procedures have contributed to the advancement of this field. The DE-based approach that was introduced in [3] was one of the earliest methods that were used for RDH. A measure of the dissimilarity between neighboring pixels in the surrounding area is investigated in order to add one single piece of content to the primary data. This area of study has progressed to the point where there are several notable research works in [3].

Histogram-based shifting of the bins of RDH is a specific kind of approach that is discussed in [4]. The histogram bin shifting approach finds a place in the bins to insert the single data point between the histogram's peak and zero [4]. In [5], It is proposed to use an RDH method that is based on several histograms. When computing the multiple histograms, various measure of complexes of the image are investigated and examined. After that, best-case scenario bin-picking procedure is utilized in order to extend the confidential information within the image [5].

RDH employing the Prediction Error (prE) Expansion (PEE) Techniques is another type of these methods that has been discovered to be superior than other approaches, surpassing them in every way of other techniques [6]. PEE-based RDH approaches include conducting an analysis on the pixels that surround a neighborhood in order to make a prediction about the currently active pixel. Stored data within the prE-value of the pixel in concern. Researchers have begun to focus more of their attention on PEE-based RDH strategies due to the superiority of these methods. Because of this, I am inspired to conduct additional study on PEE-based RDH approaches.

It stands to reason that an accurate predictor will produce a lower prE-value for a given value. A good predictor will create less embedding noise in the value because the data bits will be enlarged when the prE is performed. This means, the purpose of the analysis, as stated in this work, is to develop algorithmic advancements for RDH by investigating several prediction algorithms for pixels that are appropriate. In the framework of RDH, a variety of innovative pixel prediction algorithms have been presented. Within this framework, the effectiveness of a number of innovative pixel prediction algorithms has also been analyzed. A more favorable trade-off between embedding capacity and distortion has been achieved as a result of the utilization of suitable pixel prediction algorithms.

RDH is capable of several things based on the PVO [7]. The method that makes use of PVO in [7], image was divided into numerous parts that did not overlap each other. After that, the block's pixel values are ordered such that the highest one

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Comparison of Channel Equalization Schemes for MIMO-OFDM*

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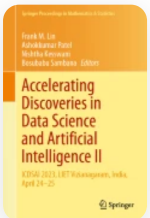

Accelerating Discoveries in Data Science and Artificial Intelligence II

(ICDSAI 2023)

C. N. Sujatha, V. Padmavathi, M. V. K. Gayatri Shivani & K. Swaraja

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Abstract

Inter-symbol interference is a major impediment to wireless communication that significantly lowers the data quality. The fundamental objective of the equalization techniques is to reconstruct the actual signal using a filter or other ways and eliminate the

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Reversible Concealment Approach using Gradients and PEE for Gray-Scale Images

Ravi Uyyala
Department of Computer Science and Engineering
Chaitanya Bharathi Institute of Technology (CBIT)
Gandipet, Hyderabad, India
uyyala.ravi@gmail.com

R Ravinder Reddy
Department of Computer Science and Engineering
Chaitanya Bharathi Institute of Technology (CBIT)
Gandipet, Hyderabad, India
rravinderreddy_cse@cbit.ac.in

***Abstract*—The need to secure our data has grown in recent years due to the increasing number of unauthorized individuals attempting to acquire protected information. In this study, we offer a new way to conceal our data—reversible data hiding (RDH). The secret information might be in the shape of an image or words. Furthermore, the concealed image is retrieved error-free as well. We can precisely recover the hidden data and cover image when the receiver needs them, according to the results reported in the study. A new approach to selecting weights based on gradients has been suggested in this method to improve prediction of the original pixel. For more accurate pixel prediction in the cover image, gradients are typically included. Using a PEE (Prediction Error Expansion) approach, the embedding has been executed. Many RDH techniques use the PEE technique, which is a simple embedding strategy. In order to gain a deeper knowledge of the RDH approaches, this proposed work makes effective use of gradients and PEE. In conclusion, the experimental results demonstrate that, compared to other previous works, the proposed work performs better.**

***Index Terms*—RDH, gradients, Histogram bin Shifting (HBS).**

I. Introduction

The proliferation of digital media (video, audio, and images) and decentralized settings has led to increased data exchange among network systems. Hidden meanings are usually included in this data. For that reason, safeguarding sensitive data is of the utmost importance. One kind of data hiding art is data concealing, which involves making the extra data unnoticeable. Data masking solutions often use digital images to deliver the concealed message. There is no assurance that the original cover photo can be retrieved using data concealment techniques. Sometimes referred to as lossless data hiding, Reversible Data Hiding (RDH) may restore both the original image and the hidden message. It is possible to embed the data without loss using the transform domain and the spatial domain. In the spatial domain, picture redundancy is higher than in the transform domain. As a result, the spatial domain benefits from data that is less distorted. [1].

RDH technology aims to accomplish clandestine communication while preserving the load image's integrity for more than 20 years. Research in the plain text domain using RDH techniques has yielded the most significant results since their inception. Almost all RDH techniques fall into one of three categories [2]. DE, HBS, and PEE. Because the marked media can be used to recreate the cover media, RDH is frequently called lossless data hiding. Data is added to the primary data through reversible pixel value change. Tian presented the DE method in 2003; it adds data to the pixel-difference method. Contrary to compression-dependent RDH techniques, Tian's method has the potential to provide a far larger embedding payload with little distortion [3]. When we look at the differences between neighboring pixels, we add one piece of information to the main data set. An alternate approach that was detailed in [4] is the HBS based RDH. The HBS method was used to input the individual data using the top and bottom bins of the histogram [4]. In [5], the authors propose an RDH approach that makes use of several histograms. A range of image complexity values are explored for the purpose of computing the multiple histograms. Among these methods, RDH that makes use of PEE Techniques stands out as particularly effective and excellent [5]. In order to predict the pixel, PEE-dependent RDH techniques look at a set of contextual pixels in a certain area. The PE of the right pixel contains bits of secret data. More attention has been directed towards PEE-dependent methods due to its superiority. This encourages me to delve more into PEE-based RDH methods [5].

The pixel is predicted using PEE-dependent RDH approaches by examining a group of contextual pixels in a specific region. Some confidential information is stored in the right pixel's PE. The excellence of PEE-dependent approaches has led to their increased focus. According to [6], this motivates me to explore PEE-based RDH approaches further.

Accordingly, the stated goal of the research is to investigate appropriate pixel prediction systems with the aim of developing novel RDH approaches. The realm of RDH has seen the introduction of novel contextual pixel methods. The capacity to compromise between deforming and embedding has evolved with the use of reliable pixel prediction algorithms. How well RDH works depends on the specific situation. One other type of PEE-based approach is the reference pixel (RP) approach. Reading through references [7], [8] reveals a number of RP and non-RP methods

Respecting the PVO, RDH's capability varies [9]. The pixel values have changed noticeably when the PVO-based approach was used. After the image is segmented into non-

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Selective Context-Based Estimation and PEE for High-Fidelity Images

Ravi Uyyala and R Ravinder Reddy

Department of Computer Science and Engineering, Chaitanya Bharathi Institute of Technology (CBIT), Gandipet, Hyderabad, India
E-mail : uyyala.ravi@gmail.com, rravinderreddy_cse@cbit.ac.in

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Abstract- An increasing number of criminals are trying to get their hands on sensitive information, which has increased the urgency with which we must secure our data. Reversible data hiding (RDH) is a novel approach to data concealment that we provide in this research. The coded data can take the form of text or an image. In addition, the hidden image is also successfully retrieved without any mistakes. Based on the study's findings, we can accurately retrieve the secret data and cover image at the exact moment the receiver requires them. In order to enhance the prediction of the original pixel, this method proposes a new way to choose weights based on Selected Context. Incorporating selective Context into the cover image allows for more precise pixel prediction. The embedding has been carried out using a PEE technique. A simple embedding strategy, the PEE technique is used by several RDH systems. This proposed study makes good use of selected Context and PEE to learn more about the RDH techniques. To sum up, the experimental results show that the suggested approach outperforms other earlier efforts.

Index Terms—Histogram bin Shifting (HBS), RDH, gradients, and PEE.

I. INTRODUCTION

Covert lossless recovery, integrity authentication, and secret information concealment are just a few of the many uses for REVERSIBLE data hiding (RDH). The use of multimedia files, including images and audio, is made easier by the everevolving transmission technology. Secure data embedding and lossless content recovery are two of RDH's key features, making it ideal for use in the medical, military, and other sensitive industries. The majority of the image RDH techniques that have been suggested thus far have focused on either enhancing forecast accuracy or decreasing distortion in embedding. Most prediction methods, such as multi-predictors, gradient adaptive predictor GAP, DP, and MEDP, aim to increase the accuracy of predictions. Predictor algorithms that use surrounding pixel similarity to target pixel similarity are not precise enough for complicated distributed images since they are local and linear. To enhance prediction accuracy, it is essential to investigate a Worldwide, non-linear forecasting model [1].

In contrast to prediction methods, embedding approaches work to lessen the impact of data distortion. To embed the information, Tian et al [2], suggested the difference expansion (DE) method, which involves increasing the difference between neighboring pixels. Using the correlation between nearby pixels, Thodi et al [3], suggested the PEE. Pairwise PEE takes into account the correlations among prediction errors based on PEE. In addition, the hybrid PEE enhances pairwise PEE by incorporating intelligent matching of pixels and personalized map selection. The method described in [3] as histogram shifting (HS) uses the top bin of an image's histogram to store data.

A suggested hybrid of PEE and HS, PEH uses prediction errors to build a statistical histogram that, in turn, generates suitable thresholds for efficient prediction error selection. Many works have been suggested to improve upon PEH by creating a more accurate histogram; one such effort is the skewed PEH, which employs extreme predictors to produce visually appealing results [3].

Compared to other approaches in this class, RDH using PEE techniques [3] is superior and better. Predictions about the pixel are provided by PEE-based RDH algorithms by analyzing nearby pixels. You can use the pixel's PE to conceal information in a picture. More research has focused on PEEbased techniques for data concealment than any other method because of how effective they are. I am now more motivated to explore the subject of RDH approaches using PEE in further detail.

A lower PE will inevitably result from using a better predictor for every particular pixel value. Due to its expansion into the lower PE, a robust pixel predictor reduces distortion caused by pixel insertion. Consequently, this paper's research aims to investigate suitable high-embedding strategies to design novel RDH approaches. Updated pixel prediction algorithms are now available for RDH. In this situation, researchers have examined the efficacy of various cutting-edge methods. An improvement in the embedding capacity versus distortion trade-off has been achieved through the deployment of appropriate pixel prediction algorithms.

Early work on image coding had a major effect on prediction methods. If you want to know how much a pixel is worth right now, the MED predictor says to check its top, left, and top-left neighbors, paying close attention to whether or not an edge is there at the pixel's left or top edge. Also used to forecast a pixel's value in the RDH approach are the Gradient predictors [[4], [5], [6], [7], [8], [9], [10], [11], [12] and [13]].
The prediction and embedding methods are equally vital in real-world applications. The PVO method was suggested

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Pixel Value Ordering Based Prediction for High-Fidelity Images

Ravi Uyyala
Department of Computer Science and Engineering
Chaitanya Bharathi Institute of Technology (CBIT)
Gandipet, Hyderabad, India
uyyala.ravi@gmail.com

Padmavathi Vurubindi
Department of Computer Science and Engineering
Chaitanya Bharathi Institute of Technology (CBIT)
Gandipet, Hyderabad, India
padmavathiv_cse@cbit.ac.in

Anila M
Department of Computer Science and Engineering
Chaitanya Bharathi Institute of Technology (CBIT)
Gandipet, Hyderabad, India
anila_cse@cbit.ac.in

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***Abstract*—Pixel Value Ordering is a method of Reversible data hiding (RDH) where the pixels in a block are arranged in a proper order for predicting the single pixel value. The secret data bits will be embedded based on the highest or lowest value within the blocks. This work presents a PVO method using Quad-tree decomposition for RDH. Initially, the Quad-Tree decomposition technique has been used for decomposing the image into various uniform blocks which are optimized for better embedding. For a better understanding of the image pixel values pair-wise prediction error technique has been proposed in this work. A 2-D mapping scheme has been proposed for better correlation among the prediction errors. The suggested strategy performs better than previous RDH techniques, according to experimental results.**

***Index Terms*—Reversible data hiding; Pixel value ordering; Quad-tree decomposition.**

I. Introduction

The RDH approach has been developed over more than 20 years to achieve covert communication while simultaneously maintaining the integrity of the load image. The plain text domain RDH methods were the first to be developed and have seen the most progress in terms of research. The explosive growth of the Internet and the broad availability of personal computers have made the Internet accessible to more people than ever before, yet with this convenience comes a growing risk of information leakage [1].

The initial image context is known to be important in conventional RDH. Correlation and redundancy are, however, always completely removed from secured images. As a remedy to this emerging issue, RDH has been proposed and is gaining popularity. Data hiding is employed to safeguard and verify the authenticity of confidential data put into the source Image. The objective of data hiding is to hide information while minimizing any loss in quality. However, there is no assurance that the original data can be restored. Applications in the military, medical diagnostics, and finance, among others, cannot tolerate the loss of original data or distortion of the core data. RDH was proposed as a solution to this problem [1]. The primary goal of RDH methods is to embed information in a way that allows for the recovery of both the original and secret information during the extraction process. There are just four broad types of RDH practices. 1. Lossless compression, uses lossless compression to accommodate new data. 2. Difference expansion, which uses a transform on invertible integers to accomplish data embedding, 3. histogram shift, which changes the gray-scale histogram to incorporate extra data, and 4) PEE is an enhanced form of histogram shift in which a PE is used in place of a gray-scale histogram.

In a DE-based process, raising the gap between nearby pixels incorporates the watermark. A further method [1] developed for color images generates a color-channel-specific vector of pixel values by use of difference expansion. The bins of the expandable difference histogram are changed in the work rather than a real location map being used.

Efficient HBS is also suggested in [1] as a concept. HBS is the usual name for this method. The authors of [1] suggest using a PEE-based embedding for RDH. The compressibility of location maps is improved by PEE-based data embedding in comparison to traditional DE-based techniques. Since PEE-based methods minimize distortion while embedding, they have become more common in RDH. To hide the watermark, these methods enhance the difference between the actual and expected pixel values. PEE efficiency is influenced by how acute the lower levels of the PEH are. There have been numerous attempts to find cutting-edge strategies for predicting pixel values with the lowest possible PE. As an illustration, in [1] we can anticipate the value of a pixel by looking at its upper, left, and upper-left neighbors. To embed the watermark, the interpolation method in [2] introduces interpolation flaws and magnifies them. In [2], the center pixel value is predicted via bi-linear interpolation based on the values of its four diagonal neighbors. It has been suggested in [2] that we use the Delaunay-triangulation technique in conjunction with distributed interpolation.

A novel approach to embedding has been proposed in [3]

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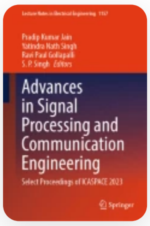
Multiclass Classification of Camouflage Images Using Combined WLD and LPQ Feature Set Using a ANN Classifier

| Conference paper | First Online: 04 July 2024

| pp 85–97 | Cite this conference paper



Advances in Signal Processing and Communication Engineering

(ICASPACE 2023)

Isha Padhy, Priyadarshi Kanungo & Sampa Sahoo

Part of the book series: Lecture Notes in Electrical Engineering ((LNEE,volume 1157))

Included in the following conference series:
International Conference on Advances in Signal Processing And Communication Engineering

79 Accesses

Abstract

Locating objects by creating a bounding box and labelling it with the object name is easy but difficult for camouflaged images. The current work focuses on multi-class image

Optimum Supply Voltage for High Gain Amplifier in Telemetry Circuitry for Ultra-Low Power Implantable Cardiac Pacemaker

Manisha G[1], Amit Krishna Dwivedi[2], Uma Maheshwari V[3], Prasun Chakrabarti[4], Martin Margala[1]

[1]School of Computing and Informatics, University of Louisiana at Lafayette, USA

[2]School of Engineering, University of Warwick, Coventry CV4 7AL United Kingdom

[3]Department of CSE, Chaitanya Bharati Institute of Technology, Hyderabad, Telangana, India

[4]ITM SLS Baroda University, Vadodara 391510 Gujarat, India

manishaguduri@ieee.org, a.k.dwivedi@ieee.org, umamaheswari@ieee.org, deputyprovost@itmbu.ac.in, martin.margala@louisiana.edu

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Abstract - This work investigates the deep subthreshold device size for the CMOS logic gate inverter circuit at the 16-nm technology node using a predictive technology model (PTM). The device's channel length (L) is established in order to acquire the optimal threshold voltage at 150 mV of the supply voltage. Using the same source voltage, the aspect ratio of an inverter logic circuit is determined, and the analysis of symmetrical transient responses is carried out. When the aspect ratio equals 3.52, the inverter logic gate is found to be symmetrical. The propagation delay is also extracted, and the achieved results demonstrate that a higher aspect ratio can facilitate high-performance circuit design. For the 16-nm technology node, the optimal threshold voltage is achieved at L=66 nm. In this work, the minimum energy point (MEP)/ Optimum Supply Voltage (OSV) is also attained at a supply voltage of 150 mV. MEP/OSV ensures improved performance and minimal power dissipation in the circuit. Based on the results achieved in this research work, a high-gain amplifier circuit in telemetry circuitry at MEP is designed and discussed. The functionality of the high-gain amplifier is verified at the optimum supply voltage.

Keywords: Device sizing, energy efficient circuit, minimum energy operation, amplifier.

I. Introduction

Smart technology is making interesting breakthroughs in almost every field, such as smart teeth, smart glasses, wearable transistorized battery-powered pacemakers, artificial biomedical devices, Bionic eyes, and smart skin. To operate/work with minimum energy sources, ultra-low power consumption is desirable to reduce the size of a device. Earlier the device's starting point was the minimum delay point which is located in the subthreshold operation region and suitable for applications where performance is not a major issue, such as energy harvesters [1]-[3]. Energy consumption and high performance are the most important design concerns. Thus, the initial design point progressed from minimum delay to minimum energy point, found in the deep sub-threshold operation region. In the deep sub-threshold functioning zone, this design starting point can be identified. It's known as the minimum energy point (MEP), and it results in the least amount of power consumption [4]. The gate voltage of CMOS devices is greater than the threshold voltage, $V_{GS} > V_T$, while operating in a normal configuration. This is an operation that takes place in a strong inversion region. For $V_{GS} < V_T$, CMOS does not conduct current in the ideal case. A current path for the flow is created between the drain and the source terminals by a number of charge carriers. Because the inversion layer of carriers has not yet formed, CMOS are in the weak inversion area which is also known as the sub-threshold region of operation [5]. The reduction in the power dissipation and the reliability of the device can be maintained by keeping the supply voltage relatively low or reduced which indirectly requires the threshold voltages of the transistor to be scaled down to maintain the device throughput and less noise. As a result, there is a significant increase in the leakage currents (Gate oxide tunnelling leakage (I_T), Gate current due to hot-carrier injection (I_{HCJ}), Reverse-bias junction leakages (I_{RB}), Gate Induced drain Leakage (I_{GDL}), and Subthreshold leakage (I_{SUBL}),) in the subthreshold region.

In the deep sub-threshold region, the deep sub-threshold current dominates the gate current (I_G) mainly due to the dependence on V_{DD}. Furthermore, leakage components such as gate-induced drain leakage (I_{GDL}) and junction leakage (I_{JL}) are also very insignificant in the subthreshold region. As a result, for the supply voltage V_{DD} in the deep sub-threshold region, the total current is driven by the deep sub-threshold current [6]. The deep sub-threshold leakage current is one of the major concerns of a MOSFET which cannot be ignored as it is comparably higher than other leakage currents and contributes to the leakage power (static power) dissipation in a substantial portion of the total power dissipation (sum of dynamic power dissipation and static power dissipation) for ultra low-power applications. In the deep subthreshold region, $V_{GS} < V_T$, the subthreshold leakage current is the current flowing between the source terminal and the drain terminal of a MOSFET. Over the last decades, it has been clearly demonstrated that a Pareto-optimal design curve can be obtained for a given design and technology, which defines as the minimum energy required for a given performance of the circuit (& vice versa) over a set of certain design parameters such as supply and threshold voltages, and especially device sizing [4], [5]. As the supply voltage approaches the lower value V_{DD}, the device operates in the deep subthreshold region which increases the proportion delay leading to a rise in static (leakage) energy in the subthreshold region. The focus has shifted as energy has quickly become the most compelling design concern. Over the last five years, research has shown that the energy-delay curve's extreme opposite, the minimum energy point (MEP), is also attractive. With the increasing demands of low-power sensors and biomedical applications requiring ultra-low energy, instead of beginning with a design optimized for optimum

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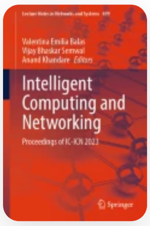
Virtual Machine Load Balancing Using Improved ABC for Task Scheduling in Cloud Computing

| Conference paper | First Online: 05 August 2023

| pp 251–264 | Cite this conference paper



Intelligent Computing and Networking

(IC-ICN 2023)

Reddy N. Hanuman, Amit Lathigara, Rajanikanth Aluvalu & Uma Maheswari Viswanadhula

Part of the book series: Lecture Notes in Networks and Systems ((LNNS,volume 699))

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Abstract

Computing resources are now more accessible, powerful, and inexpensive than ever before thanks to the widespread adoption of the Internet and rapid advancements in processing and storage technology. Thanks to this development in expertise, a new kind

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Scheduling the Tasks and Balancing the Loads in Cloud Computing Using African Vultures-Aquila Optimization Model

| Conference paper | First Online: 05 August 2023

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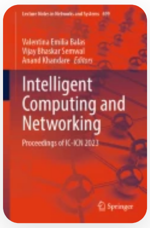

Intelligent Computing and Networking

(IC-ICN 2023)

K. L. Raghavender Reddy, Amit Lathigara, Rajanikanth Aluvalu & Uma Maheswari Viswanadhula

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Abstract

Load balancing among VMs is crucial for optimizing the delivery of cloud services, both in terms of the money spent and the time spent. Transferring a running virtual machine

House Price Rate Change Prediction using Machine Learning

RRavinder Reddy
Department of CSE
Chaitanya Bharathi Institute of Technology
Hyderabad, India
rravinderreddy_cse@cbit.ac.in

E Padmalatha
Department of CSE
Chaitanya Bharathi Institute of Technology
Hyderabad, India
epadmalatha_cse@cbit.ac.in

S Durga Devi
Department of CSE
CBIT
Hyderabad, India
sdurgadevi_cse@cbit.ac.in

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***Abstract*: The real-estate market is the central tenet amongst the most focused businesses regarding pricing and it is keep fluctuating. The rate change is normal for most of the business in the real world scenario, most of the businesses will be linearly incremented not in a drastic manner, but in the real-estate sector the price change is very drastic either increment or decrement. Based on the different global and local geopolitical factors it is varying. These factors will highly influence on the price of the property. The term valuation of a property is considered as the analytical process of evaluating the net worth of the property. However, there are a wide range of factors which affect the valuation process. In prediction of the prices there are so many approaches are there based on machine learning and analytics. Majorly the regression based approaches are giving appropriate results. But in certain circumstances it is going to deviate and sudden price spike may not be reflected there. The main objective of this study is to find such rate changes along with the correlation of the global or national circumstances. The prediction or forecast the future house prices that are generated by using Linear Regression Model. Here Hyderabad region dataset is considered, which has more fluctuated rates compared to any other metropolitan cities in the past two decades.**

Keywords—Lasso Regression, Linear Regression, Machine Learning, Feature Engineering.

I. INTRODUCTION

House is considered as one of the most important need in human's life along with other basic needs such as food and water. As peoples living standards are improving gradually over years, demand for houses is also growing simultaneously. Some people buy house as an investment and property, but most people in the world are buying a house for their shelter and livelihood. Markets related to houses always show good impact on a country's economy, which is an important factor.

Housing prices are always shows the impact on the economy. Today buyers and sellers are exhibiting great interest to know the range of housing prices. Prediction of house prices can be helpful for the people while buying a house. Most of the real estate companies developed their websites to create awareness of the house prices in different locations. Some of the real-estate sites are there to know the price of the house and size, these companies also uses the machine learning techniques for predicting and forecasting the house prices.

The price change is very dynamic in the real estate sector, which is influenced by various external factors like recession, jobs, market condition and density of the population. The internal factors that affect the living condition such as crime rate, pollution, populations and facilities. Due to several factors demand for houses is increasing every year, indirectly leading house price are increasing every year. Property demand and location may influence the house prices further, thus most of the people and real estate industry want to predict the house prices accurate. They want know the attributes or the exact factors influencing the house prices, which helps us to know the future house price. The price prediction is crucial in the real estate sectors. The developments and involvement of artificial intelligence in one's daily life, the machine learning based models are used to predict the price more accurately. Predicting these dynamic changes is difficult in the real time. The existing work considers only internal factors; here external factors are also considered for the price change prediction. Models are build using Machine Learning algorithms and algorithms from data, and the future data are predicted with them. It consists of learning methodologies such as supervised and unsupervised learning. In supervised learning there are few common algorithms, such as regression, classification, neural network and deep learning. Using linear Regression algorithm by estimating the following fields: area, age, average area, income, house_age, number of rooms, year, nitric oxide concentration, crime rate, area population, price, average area of rooms. The most influencing field amongst the above data is identified for the house price change prediction. The coorelation of these fields with the price of the will identify the influencing features. With linear regression algorithm observing and analyzing each field and which is the most influencing field in the dataset.

The house price prediction model provides many advantages to the buyers, builders and investors.

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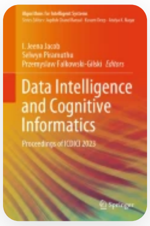
A Model for Privacy-Preservation of User Query in Location-Based Services

| Conference paper | First Online: 07 January 2024

| pp 113–125 | Cite this conference paper



Data Intelligence and Cognitive Informatics

(ICDICI 2023)

V. Sravani, O. Krishnaveni & Anila Macharla

Part of the book series: Algorithms for Intelligent Systems ((AIS))

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Abstract

Location-based services (LBS) can be a valuable tool for users seeking to find Points of Interest (POIs), but concerns about location privacy have become more prevalent in recent years. This research developed a privacy-preserving spatial keyword search method that enables users to look for POIs based on keywords without disclosing their

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Attaining Information Reliability Over Web Through Quantum Key Distribution

| Conference paper | First Online: 13 August 2024

| pp 367–379 | Cite this conference paper

Pervasive Knowledge and Collective Intelligence on Web and Social Media

(PerSOM 2023)

Padmavathi Vurubindi, Sujatha Canavoy Narahari, Aashritha Rayala & Shivani Sarikonda

Part of the book series: Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering ((LNICST,volume 517))

Included in the following conference series:
International Conference on Pervasive Knowledge and Collective Intelligence on Web and Social Media

106 Accesses

Classification and Separation of Images Received in File Sharing Applications Using Machine Learning

Koripelli Kartheesh Reddy(✉), Sai Akhil Podduturi, and G. Vanitha

Department of Computer Science and Engineering, Chaitanya Bharathi Institute of Technology, Hyderabad, Telangana, India
kartheeshreddy22@gmail.com, gvanitha_cse@cbit.ac.in

Abstract. Nowadays, applications like WhatsApp, Telegram etc. are widely used for sharing images by students during their academics. The images that are shared through these applications include printed notes, handwritten notes, question papers, circulars, marksheets and many more. In due course of time, the storage capacity of mobile phones gets filled up. All these images are stored in a single media folder and get mixed up. Since there are many categories, searching for a particular kind of image would be tedious. To reduce the task of manual deletion of images and to sort the images according to their category, this paper describes the design of a model that will extract the image into its respective folder.

Keywords: Handwritten notes · printed notes · circulars · convolutional neural networks (CNN) · image classification · deep learning · artificial neural network

1 Introduction

There is a growing need for automated approaches to classify and separate various types of documents, particularly in the context of digitalization and data management. Handwritten notes, printed notes, circulars, question papers, and mark sheets are just a few examples of many types of images that need to be organized and managed in both academic and professional settings. Manual sorting and organizing of these documents can be tedious, error-prone, and time-consuming, especially when the volume of documents is large.

To address this issue, we can employ machine learning methods like Convolutional Neural Networks (CNNs). CNNs, a type of artificial neural network, excel at image classification tasks and have seen success in fields including object recognition, facial detection, and medical image analysis.

In this paper, we propose a method for automatically classifying and separating handwritten, printed notes, circulars, question papers, and mark sheets using CNN. Our approach involves collection and preprocessing a dataset of images of these documents, designing, and training a CNN on the dataset, and evaluating the performance of the trained model on a separate test set. We demonstrate the effectiveness of our approach through a series of experiments and provide a thorough analysis of the results.

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https://doi.org/10.2991/978-94-6463-252-1_39

Serverless Computing Concepts, Technology and Architecture

Rajanikanth Aluvalu (/affiliate/rajanikanth-aluvalu/423363/), Uma Maheswari V. (/affiliate/umamaheswari-v/451045/)

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Description & Coverage

Description:

Serverless computing has emerged as a transformative technology, gaining prominence over traditional cloud computing. It is characterized by reduced costs, lower latency, and the elimination of server-side management overhead, and is driven by the increasing adoption of containerization and microservices architectures. However, there is a significant lack of comprehensive resources for academic research purposes in this field.

Serverless Computing Concepts, Technology, and Architecture addresses this gap and provides a comprehensive exploration of the fundamental concepts, characteristics, challenges, applications, and futuristic approaches of serverless computing. This book serves as a valuable reference for doctorate and post-doctorate research scholars, undergraduates, and postgraduates in fields such as computer science, information technology, electronics engineering, and other related disciplines. **Serverless Computing Concepts, Technology, and Architecture** is poised to be a one-stop reference point for those seeking to understand and harness the potential of serverless computing. It will serve as a prominent guide for researchers in this field for years to come, enriching their knowledge and advancing the study of serverless computing.

Serverless Computing Concepts, Technology, and Architecture delves into the intricate details of this cutting-edge technology, and equips readers with the knowledge to harness its full potential in their research and real-world applications. Its comprehensive coverage includes AWS Lambda, benefits and challenges of containerization, micro service architecture, visual studio code, Function as a Service (FaaS), and much more. This extensive reference book ensures that readers, from doctoral candidates to seasoned professionals, have a reliable source to turn to in the coming years. By addressing the needs of those in pursuit of advanced research, this book stands as an essential cornerstone in the study and advancement of serverless computing.

Coverage:

The many academic areas covered in this publication include, but are not limited to:

- AWS Lambda
- AWS Lambda Configuring Options
- Comparison with Cloud Computing
- Container Types
- Containerization Benefits
- Defining Serverless Computing
- Development Environment and Tools

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In Press, Corrected Proof What's this?

Security, privacy, and trust management of IoT and machine learning-based smart healthcare systems

M. Venkata Krishna Reddy [a], Premkumar Chithaluru [b], Pallati Narsimhulu [c], Manoj Kumar [d e]

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Abstract

The convergence of Internet of Things (IoT) and Machine Learning (ML) technologies has introduced innovative smart healthcare systems that have the potential to revolutionize patient care and medical diagnostics. However, this advancement also brings significant challenges in security, privacy, and trust management. This chapter provides an overview of the critical aspects related to these challenges in IoT and ML-based smart healthcare systems. The interconnected nature of IoT devices and the vast volume of data they generate in healthcare settings make these systems susceptible to various security threats, including data breaches, unauthorized access, and device tampering. Robust privacy safeguards are necessary to protect sensitive patient data and comply with data protection regulations. Trust management is essential for ensuring the dependability and integrity of these systems, requiring secure data exchange and reliable decision-making in critical medical scenarios. The chapter explores trust models and mechanisms suitable for IoT and ML-enabled healthcare ecosystems and recommends techniques like differential privacy and federated learning for patient data protection. In conclusion, it underscores the need for comprehensive solutions integrating advanced technologies and best practices to safeguard patient data and build trust among healthcare stakeholders, thereby maximizing the benefits of smart healthcare systems.

Introduction

A staggering 75 billion smart gadgets are expected by 2025 due to the IoT rapid development [1]. Many industries are adopting the IoT, including health care, transportation, and industrial automation. IoT aids in enhancing smart systems in health care, education, residences, agriculture,

PRIVACY AND SECURITY CHALLENGES IN IOT APPLICATIONS

Abstract

The Internet of Things (IoT) is becoming an increasingly vital part of modern culture. New technologies like IoT have an impact on the world today. This has resulted in our being encircled by an abundance of technological marvels. These high-tech gadgets simplify and expedite our daily lives. However, we are vulnerable to a wide variety of dangers and cyberattacks. Our personal information is always at risk. There will be several security and privacy concerns due to the widespread nature of IoT technologies. To guarantee precise and accurate confidentiality, integrity, authentication, and access control, among others, IoT requires security and privacy solutions that are credible, inexpensive, efficient, and effective. In this study, we explore the varied uses of IoT and the associated security risks along with potential future research directions for securing and protecting the Internet of Things.

Keywords— Internet-of-Things (IoT), IoT applications, privacy, security

Authors

M. Venkata Krishna Reddy
Department of Computer Science and Engineering
Chaitanya Bharathi Institute of Technology (A), Hyderabad, Telangana, India
krishnareddy_cse@cbit.ac.in

G. Mamatha
Department of Computer Engineering and Technology
Chaitanya Bharathi Institute of Technology (A), Hyderabad, Telangana, India
gmamatha_cet@cbit.ac.in

Dr. L. Raghavender Raju
Department of Computer Science and Engineering
Matrusri Engineering College, Hyderabad, Telangana, India
lraghavendarraju@matrusri.edu.in

D. Naga Jyothi
Department of Artificial Intelligence and Machine Learning
Chaitanya Bharathi Institute of Technology (A), Hyderabad, Telangana, India
dnagajyothi_cseaiml@cbit.ac.in

Dr. E. Padmalatha
Department of Computer Science and Engineering Chaitanya Bharathi Institute of Technology (A),Hyderabad, Telangana, India
epadmalatha_cse@cbit.ac.in

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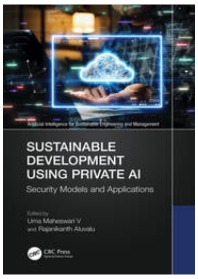

Advancing Privacy in AI

Homomorphic Encryption and Private AI

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,
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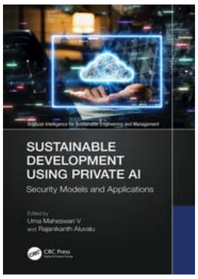

Encryption and Decryption Algorithms in Private AI

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Electronics and Communications Technology

Digital Transformation in the Customer Experience

Editors: Mohammed Majeed, PhD
Aryan Chaudhary
Raman Chadha, PhD

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Technology is an indispensable part of the business world with firms using digital platforms to gain/create, maintain and deliver customer experience, especially post-pandemic. Digitization involves the comprehensive integration of digital technology into all facets of a company's operations, yielding heightened value for customers. This book, **Digital Transformation in the Customer Experience,** looks at how digital transformation can help both service and manufacturing firms to deliver better customer experience.

This book will enhance readers' understanding of the disruptive technologies that have brought businesses to their current digital state, including social media, artificial intelligence (AI), big data, machine learning, and the Internet of Things (IoT). Numerous examples and exhibits are employed to illustrate the book&339;s comprehensive digital framework. It presents case studies of digital implementation across diverse industries and provides implementation templates for businesses. Designed to support careers in consulting and the execution of digital strategies within companies, the book covers all essential aspects. To offer insights into practical digital transformation in real-world scenarios, the book incorporates case studies and examples spanning various industries. Its organized structure makes it accessible to students, instructors, and junior and mid-level executives. Furthermore, the book seeks to disseminate novel technical concepts and features that can be integrated into daily life for the betterment of society.

The book addresses important questions such as the relevance of e-service quality in customer satisfaction and loyalty, impact and effect of adware, malware and spyware on the digital environment, the Internet of Everything in marketing, digital entertainment, digital transformation in healthcare and more. The book also covers the impact of digitalization on education, finance and banking as well as the hospitality industry. Sensitive topics like the influence of Facebook on consumer engagement and the impact of social media marketing communications on teenagers' attitudes, etc. are also addressed in the book.

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ABOUT THE AUTHORS / EDITORS:
Editors: Mohammed Majeed, PhD
Lecturer, Tamale Technical University, Tamale, Ghana

Mohammed Majeed, PhD, is a Lecturer at Tamale Technical University, Tamale, Ghana. His current research interests include digital marketing, value co-creation, brand/branding, and social media in service organizations. Dr. Majeed has published with renowned publishers such as Emerald, Taylor & Francis, Asia-Pacific Management Accounting Association, including several book chapters with Springer and Palgrave McMillan. Dr. Majeed is a Doctor of Business Administration (DBA), a Certified Business Analyst and Consultant (ICBAC), and holds MPhil and MBA in Marketing.

Aryan Chaudhary
Chief Scientific Advisor, BioTech Sphere Research, India

Aryan Chaudhary is the Chief Scientific Advisor at BioTech Sphere Research, India. He continues to make groundbreaking contributions to the industry. Having served as the Research Head at Nijji HealthCare Pvt Ltd, he has demonstrated his expertise in leveraging revolutionary technologies such as artificial intelligence, deep learning, IoT, cognitive technology, and blockchain to revolutionize the healthcare landscape. His relentless pursuit of excellence and innovation has earned him recognition as a thought leader in the industry. His dedication to advancing healthcare is evident through his vast body of work. He has authored several influential academic papers on public health and

book proposals to consider for these topics and related areas: applied microbiology, environmental biotechnology and waste management, including environmental pollution, wastewater treatment, bioenergy, biofuel, circular economy, leachate treatment activated sludge process, environmental microbiology, agricultural microbiology, advance oxidation process, bio-electrochemical systems, bacterial genomics for wastewater treatment, and heavy metal remediation. maulinshah1979@gmail.com for more information.

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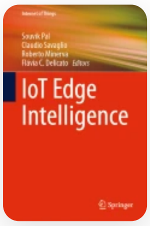

IoT Edge Intelligence

Anand Kumar Mishra, R. Ravinder Reddy, Amit Kumar Tyagi & Micheal Olaolu Arowolo

Part of the book series: Internet of Things ((ITTCC))

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Abstract

Today Edge computing is witnessing an essential interest in new use cases, especially after the introduction of 4G and 5G. Today's many applications/sectors are also heavily investing in emerging technologies like cloud computing, artificial intelligence (AI), etc., to increase the productivity and profit for their businesses. Many companies and industries are incorporating technology investments as part of their digital transformation journey. Forward-thinking organizations and cloud companies are

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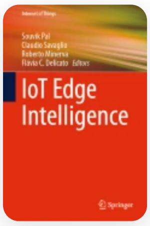

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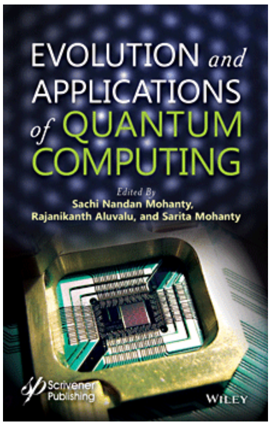

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One Line Description

The book is about the Quantum Model replacing traditional computing's classical model and gives a state-of-the-art technical overview of the current efforts to develop quantum computing and applications for Industry 4.0.

Audience

The book will be very useful for researchers in computer science, artificial intelligence and quantum physics as well as students who want to understand the history of quantum computing along with its applications and have a technical state-of-the-art overview.

Description

A holistic approach to the revolutionary world of quantum computing is presented in this book, which reveals valuable insights into this rapidly emerging technology. The book reflects the dependence of quantum computing on the physical phenomenon of superposition, entanglement, teleportation, and interference to simplify difficult mathematical problems which would have otherwise taken years to derive a definite solution for. An amalgamation of the information provided in the multiple chapters will elucidate the revolutionary and riveting research being carried out in the brand-new domain encompassing quantum computation, quantum information and quantum mechanics. Each chapter gives a concise introduction to the topic.
The book comprises 18 chapters and describes the pioneering work on the interaction between artificial intelligence, machine learning, and quantum computing along with their applications and potential role in the world of big data. Subjects include:
• Combinational circuits called the quantum multiplexer with secured quantum gate (CSWAP);
• Detecting malicious emails and URLs by using quantum text mining algorithms to distinguish between phishing and benign sites;
• Quantum data traffic analysis for intrusion detection systems;
• Applications of quantum computation in banking, netnomy and vehicular ad-hoc networks, virtual reality in the education of autistic children, identifying bacterial diseases and accelerating drug discovery;
• The critical domain of traditional classical cryptography and quantum cryptography.

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Author / Editor Details

Sachi Nandan Mohanty received his PhD from IIT Kharagpur, India in 2015, with MHRD scholarship from the Govt of India. He is now an associate professor, VIT-AP University, Andhra Pradesh. He has published more than 100 research articles in international journals as well as edited 24 books including many with the Wiley-Scrivener imprint. His research areas include data mining, big data analysis, cognitive science, fuzzy decision-making, brain-computer interface, cognition, and computational intelligence.

Rajanikanth Aluvalu, PhD, is a professor in the Department of IT, Chaitanya Bharathi Institute of Technology, Hyderabad. He is a senior member of IEEE and his specialization is in high-performance computing. He has published 90 + research articles in peer-reviewed journals and conferences.

Sarita Mohanty is an assistant professor in the Department of Master in Computer Application, Centre for Post Graduate Study, OUAT, Govt of Odisha, India. Her research areas include digital forensics and cybersecurity. She has more than 10 years of teaching experience.

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Evolution and Applications of Quantum Computing

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Fundamentals of Quantum Computing and Significance of Innovation

Swapna Mudrakola, V. Uma Maheswari, Krishna Keerthi Chennam, MVV Prasad Kantipudi

Book Editor(s):Sachi Nandan Mohanty, Rajanikanth Aluvalu, Sarita Mohanty

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Summary

Digital transformation has changed the lifestyle of people, business applications, scientific approaches, and communication systems. Data security and protection plays important role in network systems and data repositories. The latest security techniques are being solved by many contemporary attacks. The traditional cryptography techniques applied to binary data, encryption, and decryption use keys. The keys are predicted and broken using hacking methods during the transmission of data. Cryptographic techniques are upgraded using different schemes. The security can be improvised using quantum computing in data transmission of qubits form of data. The property of qubits is liable with the no-cloning theorem, not possible to make no copies. The quantum theory principle can be operated using polarization with qubits and photons. The uncertainty in quantum computing on qubits can be asses at due to wrong polarization angles. The quantized properties are used to encryption of the data using photons. Quantum Key Distribution will share the keys.

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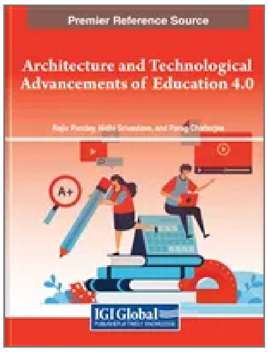

Position of Blockchain: Internet of Things-Based Education 4.0 in Industry 5.0 – A Discussion of Issues and Challenges

Shrikant Tiwari (/affiliate/shrikant-tiwari/456485/), R. Ravinder Reddy (/affiliate/r-ravinder-reddy/456486/), Amit Kumar Tyagi (/affiliate/amit-kumar-tyagi/369151/)

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Abstract

The convergence of Education 4.0 and Industry 5.0 represents a transformative paradigm shift in both the educational and industrial landscapes, driven by advanced technologies such as blockchain and the internet of things (IoT). This chapter discusses the opportunities and challenges associated with the integration of these technologies within the context of Education 4.0 and Industry 5.0. Next in the industrial sector, Industry 5.0 is characterized by the seamless integration of digital technologies, automation, and data-driven decision-making. Blockchain technology enhances transparency, security, and trust in supply chains, while IoT devices provide real-time data for optimizing processes (including few challenges like scalability, interoperability, cost, etc.). In the educational sector, Education 4.0 emphasizes personalized learning, digital literacy, and lifelong learning. Blockchain ensures the security and immutability of educational credentials, while IoT facilitates personalized learning experiences (with few challenges like data privacy, etc.).

Chapter Preview

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1. Introduction

Industry 5.0 is the next evolution of the manufacturing industry, where smart factories use emerging technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and blockchain to create a more connected and efficient manufacturing process. The integration of blockchain technology and IoT devices in Industry 5.0 has the potential to create new opportunities for businesses and consumers. However, this integration also presents several security, privacy, and technical challenges that need to be addressed to ensure the success of this emerging ecosystem. This paper aims to explore these challenges in detail and proposes potential solutions. Security challenges include the vulnerability of IoT devices to attacks and the need for secure communication between devices. Privacy challenges arise from the large amount of data generated by IoT devices and the need to protect user data. Technical challenges include the scalability of blockchain technology, interoperability between different blockchain networks, and the energy consumption of blockchain mining. Addressing these challenges is important to ensure the successful integration of blockchain and IoT in Industry 5.0. The paper will examine the potential solutions to these challenges, including the use of secure hardware modules for IoT devices and the development of consensus algorithms that reduce energy consumption. Ultimately, this paper highlights the importance of understanding and mitigating these challenges to achieve the full potential of blockchain and IoT in Industry 5.0. Now few of essential perspectives can be discussed here as:

In the rapidly evolving digital landscape, the convergence of blockchain technology and the Internet of Things (IoT) has opened up new possibilities and challenges in terms of security, privacy, and technical considerations. This combination has the potential to revolutionize various industries, ranging from healthcare and supply chain management to energy and transportation.

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1 OpenCV libraries for computer vision

From the book Computer Vision

Suresh B. Kumar, Viswanadha S. Raju and Uma V. Maheswari

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Abstract

From the last few decades, researchers are enthusiastic to develop machines that work and act as human beings. Computer vision (CV) is the most excellent field for researchers to fulfill their dreams. CV is a subfield of artificial intelligence. CV works with visual inputs like digital images and videos. Mainly it focuses on creating systems, which process and analyze the visual input data, to get meaningful information from those inputs. It aims to perform different types of operations on supplied visual inputs. Object classification, object identification, object tracking, edge detection, feature extraction and human identification are few applications of CV. To perform different types of operations, special algorithms with minimum computation time are required. Various libraries are developed to perform CV operations. Among all open sources, computer vision library (OpenCV) is the most popular and widely used open-source library for developing CV applications. OpenCV is designed to develop CV applications using inbuilt methods with less computational time. The major goal of OpenCV library is to provide a classy view to researchers with an optimized code mechanism on basic infrastructure. In OpenCV, optimized code is developed for a lot of applications like filters and edge detection. Using this optimal code, researchers can develop their applications. OpenCV supports various operating systems, including mobile operating systems. This chapter discusses developing computer visual applications using OpenCV. This will be useful for researchers to understand and use OpenCV for their applications.

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