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Multidisciplinary Insights in Modern Engineering

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Multidisciplinary Insights in MODERN ENGINEERING

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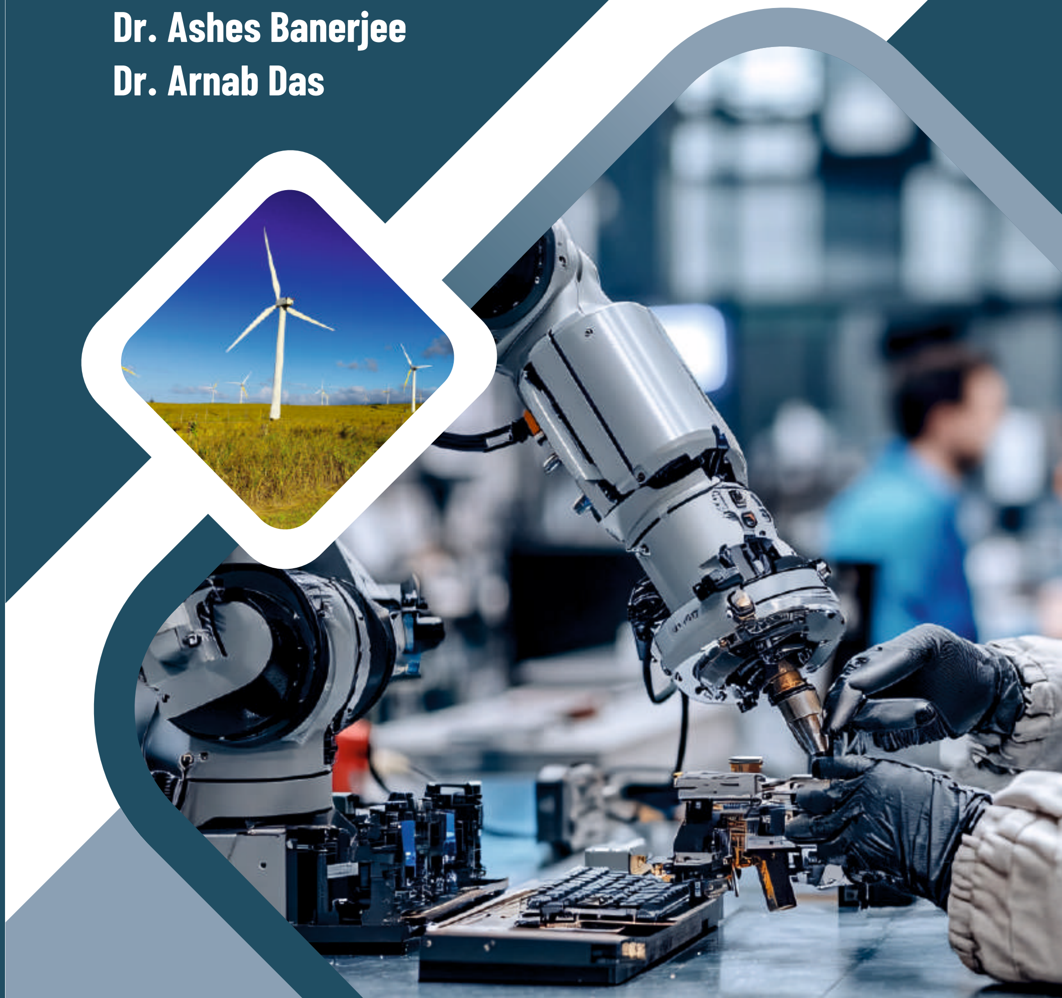
Abhishek Dhar
Dr. Ashes Banerjee
Dr. Arnab Das



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Preface

In an era defined by rapid technological advancements and increasingly complex challenges, engineering has evolved beyond the confines of individual disciplines. Modern problems demand innovative solutions that leverage expertise from multiple domains. Multidisciplinary Insights in Modern Engineering was conceived to reflect this transformative shift, offering a platform for knowledge that transcends traditional boundaries.

This book is a celebration of collaboration, integration, and innovation. It explores how disciplines such as mechanical engineering, electrical engineering, civil engineering, computer science, and materials science converge to address pressing global issues. By combining theoretical foundations with practical applications, the chapters in this book highlight the importance of interdisciplinary approaches in areas such as renewable energy, artificial intelligence, sustainable infrastructure, and advanced manufacturing.

The goal of this book is twofold: to inspire engineers and researchers to embrace a multidisciplinary mindset and to provide students with the tools they need to navigate the interconnected world of modern engineering. Through a blend of case studies, research insights, and forward-thinking perspectives, this book serves as a guide to understanding how diverse disciplines come together to create innovative solutions.

I would like to express my gratitude to the contributors whose expertise and dedication have made this book possible. I also thank the readers for their curiosity and commitment to expanding their horizons. It is my hope that Multidisciplinary Insights in Modern Engineering becomes a valuable resource, sparking new ideas and fostering collaborations that will shape the future.

Together, let us break barriers, bridge gaps, and engineer a world of endless possibilities.

Dr. Ranjan Kumar
Associate Professor,
Department of Mechanical Engineering,
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Kolkata, West Bengal, India

Acknowledgement

I extend my heartfelt gratitude to Swami Vivekananda University, Kolkata, India, for their steadfast support and encouragement throughout the creation of “Multidisciplinary Insights in Modern Engineering" The university's dedication to fostering education and research has been instrumental in shaping the content and direction of this publication. We deeply appreciate the collaborative spirit and resources provided by Swami Vivekananda University, Kolkata, which have enabled us to explore and share the latest innovations and technologies across various fields.

We hope that this book serves as a valuable resource for this esteemed institution and the broader academic community, reflecting our shared dedication to knowledge, progress, and the pursuit of excellence.

I extend my deepest appreciation to each of the external reviewers mentioned below for their unwavering commitment to excellence and their indispensable role in ensuring the scholarly merit of this work.

With sincere appreciation,

List of Reviewers:

1. Dr. Sumeet Chakraborty, University of Westlake, Hangzhou, China.
2. Dr. Anshuman Das, Dept. of Mathematics, Presidency University, Kolkata, India.
3. Dr. Debabrta Sarddar, Assistant Professor, Dept. of CSE, University of Kalyani, Kalyani, Nadia, India.

Contents

Chapter - 1
Enumerative Techniques in Combinatorics: Exploring the Structure of Permutation Groups

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Chapter - 1

Enumerative Techniques in Combinatorics: Exploring the Structure of Permutation Groups

Aratrika Pal

Abstract

Enumerative techniques in combinatorics play a crucial role in understanding the structure of permutation groups and their various applications in mathematics, computer science, and theoretical physics. These techniques focus on counting, arranging, and analyzing distinct configurations within sets, particularly involving permutations and combinations. One significant area of application is the study of permutation groups, which are central to group theory and algebraic structures.

In this context, enumerative combinatorics helps in determining the number of possible permutations, identifying symmetries, and characterizing orbits and stabilizers in group actions. Applications range from solving classical problems like finding the number of distinct ways to arrange objects, to more advanced topics such as generating functions, recurrence relations, and the Pólya enumeration theorem. These tools are crucial in coding theory, cryptography, and computational biology, where complex systems need efficient algorithms for pattern recognition and data arrangement. Additionally, enumerative methods are vital for understanding the algebraic properties of permutation groups, such as their cycle structure and conjugacy classes, which have implications in representation theory and the study of polynomial invariants. Overall, enumerative combinatorics provides a powerful framework for investigating the rich structure and behavior of permutation groups across various fields.

Keywords: Enumerative combinatorics, permutation groups, generating functions, representation theory, symmetric functions

Introduction

Enumerative combinatorics and permutation groups represent two interrelated branches of combinatorial mathematics. Enumerative combinatorics involves counting the number of ways certain patterns can be formed, while permutation groups examine the rearrangements of a set's elements and their algebraic properties. Both fields have significant implications in mathematics and computer science, particularly in algorithm design, cryptography, and statistical physics.

Enumerative Combinatorics

Enumerative combinatorics deals with counting discrete structures. Its primary techniques include generating functions, recurrence relations, and the principle of inclusion-exclusion.

Generating Functions

Generating functions encode sequences as power series. They are invaluable in solving recurrence relations and finding closed-form expressions for sequences.

- **Ordinary Generating Functions:** For a sequence an the ordinary generating function is G(an;x)=n=0anxn.
- **Exponential Generating Functions:** For a sequence an, the exponential generating function is E (an;x)= n=0anxnn!
- Recurrence Relations.

Recurrence relations express sequences in terms of previous terms. Solving these relations often involves finding characteristic equations or using generating functions.

Principle of Inclusion-Exclusion

The principle of inclusion-exclusion provides a method to count the number of elements in the union of several sets by considering intersections.

Applications

Enumerative combinatorics finds applications in diverse fields such as graph theory, where it counts the number of specific subgraphs, and in algebra, where it helps count the number of distinct algebraic structures meeting certain criteria.

Permutation Groups

Permutation groups study the symmetries of sets, which are the different ways of rearranging elements of a set. A permutation group G acting on a set S consists of permutations of S that form a group under composition.

Basic Definitions

- **Permutation:** A permutation of a set S is a bijective function from S to itself.
- **Symmetric Group Sn:** The group of all permutations on n elements.
- **Cycle Notation:** A way to represent permutations by their cycles.

Properties of Permutation Groups

Permutation groups have rich algebraic structures. Key concepts include the order of a permutation, cycle type, and conjugacy classes.

Theoem: Cayley's Theorem

Cayley's Theorem states that every group is isomorphic to a subgroup of the symmetric group. This theorem underscores the fundamental role of permutation groups in abstract algebra.

Applications

Permutation groups have applications in solving puzzles like the Rubik's Cube, analysing molecular symmetries in chemistry, and designing algorithms in computer science.

Interplay Between Enumerative Combinatorics and Permutation Groups.

Enumerative combinatorics and permutation groups intersect in various ways. One notable area is the study of permutation patterns and counting specific types of permutations.

Counting Permutations

Enumerative techniques are used to count permutations with specific properties, such as derangements (permutations with no fixed points) and permutations with restricted cycles.

Permutation Patterns

A permutation pattern is a sequence that appears as a subsequence of another permutation. Studying these patterns involves both combinatorial counting and group-theoretic properties.

Symmetry and Enumeration

Symmetry, a core concept in permutation groups, simplifies counting problems in enumerative combinatorics. The Burnside's Lemma, for example, uses group actions to count distinct objects up to symmetry.

Conclusion

Enumerative techniques in combinatorics provide a powerful and versatile framework for exploring the intricate structure of permutation groups. Through methods like counting permutations, analyzing cycle structures, and applying generating functions, combinatorics offers deep insights into the symmetries and algebraic properties of these groups. The interplay between combinatorics and group theory not only advances pure mathematical research but also fuels numerous applications across disciplines such as computer science, cryptography, and biology. By leveraging these techniques, mathematicians can solve complex problems involving symmetries, arrangements and transformations, making enumerative combinatorics an essential tool in both theoretical and applied contexts. As research continues to evolve, the relationship between these two fields will undoubtedly yield further innovations and broaden their impact in diverse scientific domains.

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Chapter - 2
An Inventory Model for Deteriorating Items with Cubic Demand and Partial Backlogging

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Chapter - 2

An Inventory Model for Deteriorating Items with Cubic Demand and Partial Backlogging

Tarak Nath Halder and A. Das

Abstract

This paper presents an advanced inventory model for deteriorating items where the demand rate follows a cubic function of the inventory level, and partial backlogging is allowed. We develop a mathematical framework to analyze the optimal inventory policy, incorporating both deterioration and cubic demand. The paper derives the optimal order quantities and reorder points and provides numerical simulations to illustrate the model's practical implications.

Introduction

Inventory management is pivotal in ensuring the efficient operation of supply chains, especially when dealing with deteriorating items. Traditional models often assume linear or constant demand, which may not accurately reflect real-world scenarios. This paper explores an inventory model where demand is a cubic function of the inventory level, a scenario that captures more complex demand behaviors. Additionally, we consider partial backlogging, which allows for fulfilling only a portion of the backlogged demand during stockouts.

Literature Review

Deteriorating Inventory Models

Inventory models for deteriorating items have been studied extensively, with many approaches focusing on the impact of deterioration on inventory levels and costs. Early models, such as those developed by Goyal and Gupta (1989) and Shah and Jaber (2004), assume exponential or linear deterioration rates. These models laid the foundation for understanding how deterioration affects inventory management.

Inventory models for deteriorating items have evolved significantly over the years. Early models, such as those by, focused on exponential deterioration rates. Recent studies have extended these models to include various deterioration patterns and their impacts on inventory management.

Cubic Demand Functions

Cubic demand functions provide a more nuanced representation of demand patterns compared to linear models. The work by introduced demand functions that vary non-linearly with inventory levels, offering a more realistic approach to modeling complex demand behaviors.

Partial Backlogging

Partial backlogging allows a fraction of the demand to be fulfilled after a stockout. Models incorporating partial backlogging, such as those by, address the limitations of models assuming complete backlogging or no backlogging.

Model Formulation

Assumptions

- Items deteriorate at a constant rate δ.
- Demand rate follows a cubic function of the inventory level: $D(S(t)) = a - bS(t) + cS(t)^2 - dS(t)^3$.
- Partial backlogging occurs during stockouts, with a fraction θ of the backlogged demand being satisfied.

Mathematical Model

Let $S(t)$ denote the inventory level at time t. The differential equation governing the inventory dynamics is:

$$\frac{dS(t)}{dt} = -D(S(t)) - \delta S(t)$$

Where $D(S(t)) = a - bS(t) + cS(t)^2 - dS(t)^3$ represents the cubic demand function.

Cost Structure

The total cost consists of ordering costs, holding costs, and shortage costs:

$$C = \text{Ordering Cost} + \text{Holding Cost} + \text{Shortage Cost}$$

The holding cost is proportional to the inventory level, and the shortage cost is a function of the backlogged demand, adjusted by the fraction θ of the demand that is eventually satisfied.

Objective Function

The goal is to minimize the total cost over a planning horizon T. The cost function is given by:

$$C = \int_0^T [hS(t) + s(\max\{0, D(S(t)) - S(t)\})]\, dt$$

Where h is the holding cost per unit per time, and s is the shortage cost per unit of backlogged demand.

Solution Method

Analytical Solution

To find the optimal order quantity Q^* and reorder point R^*, we set up the first-order conditions for minimizing the cost function. The necessary conditions are:

$$\frac{\partial C}{\partial Q} = 0$$

$$\frac{\partial C}{\partial R} = 0$$

Numerical Solution

In cases where the analytical solution is complex or infeasible, numerical methods such as dynamic programming or heuristic algorithms are employed. These methods help in solving the cost minimization problem by iteratively adjusting the order quantity and reorder point.

Numerical Examples

Example 1: Sensitivity Analysis

We analyze how changes in parameters δ, a, b, c, and d affect the optimal policy. For instance, varying the cubic coefficients in the demand function shows how different demand curves influence inventory decisions.

Example 2: Comparative Analysis

We compare the results obtained from the cubic demand model with those from linear and exponential demand models. This comparison highlights the benefits and limitations of using a cubic demand function in inventory management.

Discussion

The incorporation of a cubic demand function into the inventory model provides a more accurate representation of complex demand behaviors. The results indicate that the cubic demand model can lead to different optimal inventory policies compared to traditional linear or exponential models. Partial backlogging further enhances the model's applicability in real-world scenarios.

Conclusion

This paper presents a comprehensive inventory model for deteriorating items with cubic demand and partial backlogging. The developed model offers valuable insights into managing inventory with complex demand patterns and provides a basis for future research in this area.

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Chapter - 3
A Mathematical Model on Malaria Transmission Dynamics

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Chapter - 3

A Mathematical Model on Malaria Transmission Dynamics

Moumita Ghosh

Abstract

Malaria continues to pose a serious threat to international health, especially in tropical and subtropical areas. Every year, hundreds of thousands of people die from the disease, which is spread by Anopheles mosquitoes and caused by Plasmodium parasites. In order to assess control methods, comprehend the dynamics of malaria transmission, and direct public health initiatives, mathematical modeling has become an indispensable tool.

Keywords: Malaria, transmission dynamics, mathematical modeling, reproduction number

Introduction

Malaria remains a major public health challenge, particularly in tropical and subtropical regions. The World Health Organization (WHO) estimates that in 2020, there were approximately 241 million cases of malaria worldwide, resulting in 627,000 deaths, primarily among children under five years of age in Africa. The transmission dynamics of malaria are complex and influenced by a myriad of factors, making it essential to understand these dynamics to develop effective interventions.

The Vector: Anopheles Mosquitoes

The primary vectors of malaria are female Anopheles mosquitoes, which transmit the Plasmodium parasites during blood meals. Several species of Anopheles mosquitoes are involved in malaria transmission, with Anopheles gambiae being the most efficient vector in Africa. The lifecycle of the mosquito, including its breeding habits, feeding behavior, and longevity, plays a crucial role in the spread of malaria. Factors such as temperature, humidity, and availability of breeding sites significantly impact mosquito population dynamics and, consequently, malaria transmission.

Environmental Factors

Environmental conditions heavily influence the spread of malaria. Temperature and rainfall are two key determinants. Temperature affects both the development of the mosquito and the parasite within the mosquito. Optimal transmission occurs at temperatures between 20°C and 30°C. Rainfall creates breeding sites for mosquitoes, while humidity affects mosquito survival. Seasonal changes in these environmental factors lead to variations in malaria transmission intensity.

Human Behavior and Socioeconomic Factors

Human behavior, including sleeping habits, use of insecticide-treated bed nets (ITNs), and indoor residual spraying (IRS), greatly influences malaria transmission. Socioeconomic factors such as access to healthcare, education, and housing conditions also play a significant role. For example, poor housing may increase exposure to mosquito bites, while limited access to healthcare can delay treatment, increasing the chances of transmission.

The Parasite Lifecycle

The lifecycle of Plasmodium parasites includes both human and mosquito hosts. After being transmitted by a mosquito bite, the parasite undergoes several stages of development in the human body before being taken up by another mosquito, continuing the cycle. The parasite's ability to evade the human immune system and develop drug resistance are significant factors in the persistence and spread of malaria.

Model Formulation

Human and Mosquito Populations

SIR Model for Malaria

A common framework used in malaria modeling is the SEIR (Susceptible-Exposed-Infectious-Recovered) model. This model divides the human population into four compartments:

1. **Susceptible (S):** Individuals who are at risk of contracting malaria.
2. **Infectious (I):** Individuals who have developed the disease and can transmit it to mosquitoes.
3. **Recovered (R):** Individuals who have recovered from the disease and are temporarily immune.

The mosquito population is similarly modeled, usually with three compartments: Susceptible (S), and Infectious (I). The interaction between the human and mosquito populations is crucial in understanding the spread of malaria. Similarly, the mosquito population is divided into Susceptible Sm, and Infectious Im, compartments. The interactions between these populations are governed by the following differential equations:

dSdt = HNH-βIm/NHS-HS

dIdt = βIm/NHS-(γ+H)S

dRdt = γI-HR

dSmdt = MNM-mNHISm-MSm

dImdt = mNHISm-MIm

Where:

- NH and NM are the total human and mosquito populations, respectively.
- H and M are the natural death rates of humans and mosquitoes.
- And m are the transmission rates from mosquitoes to humans and from humans to mosquitoes.
- Is the recovery rate in humans.

Basic Reproduction Number (R_0)

The basic reproduction number, **R_0,** represents the average number of secondary infections produced by a single infected individual in a fully susceptible population. For this model, **R_0** is given by:

R0=√(mHγ+HMM)

Modeling Interventions

Mathematical models are valuable in assessing the impact of various malaria control strategies, such as:

- **Insecticide-Treated Nets (ITNs):** Reducing human-mosquito contact.
- **Indoor Residual Spraying (IRS):** Killing mosquitoes within homes.
- **Antimalarial Drugs:** Reducing the infectious period in humans.
- **Vaccines:** Increasing immunity within the population.

By adjusting model parameters, researchers can simulate the effects of these interventions, individually or in combination, to predict outcomes under different scenarios.

Challenges and Limitations

While mathematical models provide important insights, they also have limitations. The accuracy of predictions depends on the quality of data used to parameterize the models. Moreover, models often rely on simplifying assumptions that may not fully capture the complexity of malaria transmission, such as heterogeneous mosquito behavior or human mobility.

Conclusion

The spread dynamics of malaria are influenced by a complex interplay of factors, including the biology of the mosquito vector, environmental conditions, human behavior, and the lifecycle of the Plasmodium parasite. Understanding these dynamics is essential for designing effective malaria control and elimination strategies. Mathematical models provide valuable insights into the transmission patterns and potential impacts of interventions, offering a scientific basis for public health policy decisions.

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Chapter - 4
Determining Global Stability of Typhoid Fever Transmission Model Comprising Media Awareness

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Chapter - 4

Determining Global Stability of Typhoid Fever Transmission Model Comprising Media Awareness

Jayanta Mondal and Piu Samui

Abstract

Typhoid fever, one of the most life-threatening contagion declared by the World Health Organization (WHO), is brought about by Salmonella Typhi bacterium. Typhoid is predominantly spread through food resources or drinking food or water contaminated with the faces of an infected person. India has more than the 50% annual global burden of Typhoid fever. Immense usage of antibiotics is creating antimicrobial resistance that is making complications during treatment of Typhoid fever. In this study, we present a four-dimensional deterministic model of Typhoid fever taking into account the influences of media awareness in disease incidence, disease progression, prevention and control of the disease. Equilibrium points of the determined and the basic reproduction number (R_0) of the epidemic system is computed. Global stability of the system around the endemic steady state is investigated using the geometric approach. Numerical simulations are carried out in order to verify overall analytical outcomes.

Keywords: Typhoid fever, media awareness, global stability, geometric approach

Introduction

Typhoid fever, a fatal human infectious disease caused by the Salmonella enterica serotype Typhi bacteria that is also termed as Salmonella Typhi is a type of enteric fever found only in humans. According to the National Center for Disease Control (NCDC), In India, typhoid has been the most prevalent water-borne disease between 2022 and 2024, affecting about 4.5 million people annually and resulting in around 9,000 deaths [https://ncdc.mohfw.gov.in/]. According to the centers for Disease Control and Prevention (CDC) report, approximately 11-21 million cases of typhoid fever documented globally per year, causing about 135,000-230,000 deaths cases [https://www.cdc.gov/typhoid-fever/about/index.html]. According to the World Health Organization, expansion in urbanization, climate changes, increased resistance rate of antibiotic treatment is enhancing the global burden of typhoid fever [https://www.who.int/news-room/fact-sheets/detail/typhoid]. Although vaccination against typhoid fever is available from six months up 65 years, drug resistance is causing complications in proper antibacterial treatment. Plausible prevention measures of typhoid fever are antibiotics, vaccine, safe and proper practice of hygiene, safe sanitation, proper and safe practice of food and water taking etc.

Media awareness is very helpful to acknowledge people about the prevalence of a highly communicable disease, course of the infection, preventive measure, and to promote vaccination uptake. Public health departments follow various paths like TV, Radio, internet, newspapers, You Tube and social media to aware people regarding the outbreak of an infection and its possible control. In our present study, we incorporate the impact of media awareness in our proposed model. Epidemiological models have great assistance in describing the overall intricate dynamics of infectious diseases and to trace different epidemiological factors. A handful of mathematical models describing the transmission dynamics of typhoid fever have been conducted by various researchers worldwide [Adetunde 2008, Edward 2016, Edward 2017, Funk 2009, Khan 2015, Liu 2008, Mondal 2022, Mushayabasa 2013, Mushayabasa 2016, Rai 2019]. Motivated from these researches, we propose a deterministic model depicting the typhoid fever dynamics in human populations.

The article is synchronized as follows: in the very next Section, we formulate our proposed mathematical model of typhoid fever transmission. In Section 3, the equilibrium points of the epidemic system are analyzed along with their existence criteria. Moreover, the basic reproduction number of the system is computed. In Section 4, the global stability of the epidemic system is studied using the geometric approach, In Section 5, some numerical simulations are presented and analytical results are validated numerically. Conclusions regarding overall model analysis is attached.

The mathematical model

We have constructed a deterministic, four dimensional ODE model considering susceptible $S(t)$-the number of individuals who can be infected but have not yet contracted the Salmonella typhi but may contract it if exposed to any mode of its transmission; infectives $I(t)$-the number of individuals who have contracted the Salmonella typhi and are actively or capable of transmitting it; recovered $R(t)$-the number of individuals who are recovered after treatment or media awareness programs and are immune to disease and $M(t)$-the cumulative density of awareness programs driven by media. Our proposed model assumes that, due to awareness programs, uninfected population form a different class and they are sufficiently aware to avoid contacting with the infected population.

$$\begin{aligned}\frac{dS}{dt} &= \lambda - \alpha SI - \epsilon_1 bSM + \omega R - \mu S,\\ \frac{dI}{dt} &= \alpha SI - \delta I - \gamma I - \mu I,\\ \frac{dR}{dt} &= \gamma I + \epsilon_1 bSM - \omega R - \mu R,\\ \frac{dM}{dt} &= \delta_0 I - \theta M,\end{aligned} \tag{1}$$

With epidemiologically feasible initial conditions

$$S(t_0) > 0, I(t_0) \geq 0, R(t_0) \geq 0, M(t_0) \geq 0. \tag{2}$$

Here, $t = t_0$ denotes the initial day of infection where λ is the recruitment rate of individuals into the community by birth or migration (Susceptible), the per capita mortality rate of susceptible, Infected and Recovery are denoting μ. The typhoid fever-indicated mortality rate. The rate of infection is a, b be the dissemination rate of awareness programs between aware individual and uninfected population. Here ϵ_1 is the proportionality constant which governs the implementation. The constant recovery rate and disease-induced death rate of infected individualsγ and δ respectively. The constant ω denote the rate of recovery of aware susceptible due to social factor. The proportionality constant δ_0 be the rate at which the awareness campaigns by media and θ represents the depletion rate of these programs due to ineffectiveness.

Steady States

In this Section, the feasible equilibrium executed by the epidemic system (1) and their existence criteria would be studied.

Disease-Free Equilibrium (DFE)

The epidemic system (1) possesses a DFE, say, $E_0(\lambda/\mu, 0,0,0)$ and it always exists, without any epidemic condition. In this equilibrium, the whole population is free from the infection and hence there is no media awareness as well.

Now, we compute the basic reproduction number (R0) (say) of the epidemic system (1) determining the average number of secondary infections using the next-generation matrix method proposed by Driessche and Watmough [Driessche2002]. The basic reproduction number R0 for the epidemic system (1) is computed as follows:

$$R_0 = \frac{\lambda\alpha}{\mu(\mu+\delta+\gamma)}$$

Endemic equilibrium (EE)

The epidemic system (1) exhibits an endemic equilibrium (EE) $E^*(S^*, I^*, R^*, M^*)$where the components of EE (E^*) are computed as

$$\begin{aligned}
S^* &= \frac{\delta+\mu+\gamma}{\alpha}, \\
I^* &= \frac{\lambda(\omega+\mu)\left(1-\frac{1}{R_0}\right)}{(\omega+\mu)(\delta+\mu+\gamma)(\alpha+\epsilon_1 b\delta_0)-\omega\alpha\left(\gamma\theta+\epsilon_1 b\delta_0(\delta+\mu+\gamma)\right)}, \\
R^* &= \frac{\lambda(\omega+\mu)\left(\gamma\theta+\epsilon_1 b\delta_0(\delta+\mu+\gamma)\right)\left(1-\frac{1}{R_0}\right)}{(\omega+\mu)(\delta+\mu+\gamma)(\alpha+\epsilon_1 b\delta_0)-\omega\alpha\left(\gamma\theta+\epsilon_1 b\delta_0(\delta+\mu+\gamma)\right)}, \\
M^* &= \frac{\lambda\delta_0(\omega+\mu)\left(1-\frac{1}{R_0}\right)}{\theta\left((\omega+\mu)(\delta+\mu+\gamma)(\alpha+\epsilon_1 b\delta_0)-\omega\alpha\left(\gamma\theta+\epsilon_1 b\delta_0(\delta+\mu+\gamma)\right)\right)}.
\end{aligned}$$

Since all the model parameters are positive, we would get positive values of the components S^*, I^*, R^* and M^* only if $R_0 > 1$ and

$$(\omega+\mu)(\delta+\mu+\gamma) > \omega\theta\gamma + \omega\epsilon_1 b\delta_0(\delta+\mu+\gamma)$$

Remark 1: It is observed from the expression of I^* that $\frac{dI^*}{db} < 0$ and $\frac{dI^*}{d\delta_0} < 0$. This is indicating the fact that cumulative number of infective individuals is decreasing with an increase in the value of the dissemination rate of awareness and the implementation rate of awareness programs.

Global Stability Analysis

In this Section, the global stability of the epidemic system (1) is analyzed using the geometric approach proposed by Li and Muldowney [Li 1996].

Theorem 1. The infected steady state E^* becomes globally asymptotically stable in int D for $\overline{y} > 0$ ($\overline{y}$ defined in the proof) whether $R_0 > 1$.

Proof. The Jacobian matrix (J) of the epidemic system (1) is given by,

$$J = \begin{pmatrix} -(\alpha I + \epsilon_1 bM + \mu) & -\alpha S & \omega & -\epsilon_1 bS \\ \alpha I & 0 & 0 & 0 \\ \epsilon_1 bM & \gamma & -(\omega+\mu) & \epsilon_1 bS \\ 0 & \delta_0 & 0 & -\theta \end{pmatrix}.$$

Let us consider

$$\begin{aligned} p_{11} &= -(\alpha I + \epsilon_1 bM + \mu), p_{21} = -\alpha S, p_{31} = \omega, p_{41} = -\epsilon_1 bS, \\ p_{12} &= \alpha I,\ p_{22} = 0, p_{32} = 0,\ p_{42} = 0, \\ p_{13} &= \epsilon_1 bM,\ p_{23} = \omega,\ p_{33} = -(\omega+\mu), p_{43} = \epsilon_1 bS, \\ p_{14} &= 0,\ p_{24} = \delta_0, p_{34} = 0,\ p_{44} = -\theta, \end{aligned}$$

Also, it is considered that

$$\begin{aligned} A &= A(S,I,R,M) = diag(1,1,1,1,R,R) \\ Therefore,\ A_f A^{-1} &= diag\left(0,0,0,0,\frac{R\prime}{R},\frac{R\prime}{R}\right). \\ Let, B &= A_f A^{-1} + AJ^{[2]}A^{-1}. \end{aligned}$$

$$J^{[2]} = \begin{pmatrix} p_{11}+p_{22} & p_{23} & p_{24} & -p_{13} & -p_{14} & 0 \\ p_{23} & p_{11}+p_{33} & p_{34} & p_{12} & 0 & -p_{14} \\ p_{42} & p_{43} & p_{11}+p_{44} & 0 & p_{12} & p_{13} \\ -p_{31} & p_{21} & 0 & p_{22}+p_{33} & p_{34} & -p_{24} \\ -p_{41} & 0 & p_{21} & p_{43} & p_{22}+p_{44} & p_{23} \\ 0 & -p_{41} & p_{31} & -p_{42} & p_{32} & p_{33}+p_{44} \end{pmatrix}.$$

Thus, $A_f A^{-1} + AJ^{[2]}A^{-1}$ is

$$\begin{pmatrix} p_{11}+p_{22} & p_{23} & p_{24} & -\frac{p_{13}}{R} & -p_{14} & 0 \\ p_{23} & p_{11}+p_{33} & p_{34} & p_{12} & 0 & -\frac{p_{14}}{R} \\ p_{42} & p_{43} & p_{11}+p_{44} & 0 & \frac{p_{12}}{R} & \frac{p_{13}}{R} \\ -p_{31} & p_{21} & 0 & p_{22}+p_{33} & \frac{p_{34}}{R} & -\frac{p_{24}}{R} \\ -p_{41}R & 0 & p_{21}R & p_{43}R & p_{22}+p_{44} & p_{23} \\ 0 & -p_{41}R & p_{31}R & -p_{42}R & p_{32} & p_{33}+p_{44} \end{pmatrix}.$$

Now, $B = A_f A^{-1} + AJ^{[2]}A^{-1} =$

$$\begin{pmatrix} p_{11}+p_{22} & p_{23} & p_{24} & -\frac{p_{13}}{R} & -p_{14} & 0 \\ p_{23} & p_{11}+p_{33} & p_{34} & p_{12} & 0 & -\frac{p_{14}}{R} \\ p_{42} & p_{43} & p_{11}+p_{44} & 0 & \frac{p_{12}}{R} & \frac{p_{13}}{R} \\ -p_{31} & p_{21} & 0 & p_{22}+p_{33} & \frac{p_{34}}{R} & -\frac{p_{24}}{R} \\ -p_{41}R & 0 & p_{21}R & p_{43}R & p_{22}+p_{44}+\frac{R\prime}{R} & p_{23} \\ 0 & -p_{41}R & p_{31}R & -p_{42}R & p_{32} & p_{33}+p_{44}+\frac{R\prime}{R} \end{pmatrix},$$

$$\begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix}.$$

Where, $B_{11} = -(\alpha I + \epsilon_1 bM + \mu)$, $B_{12} = \left[0\ 0\ -\omega\ \frac{\epsilon_1 bM}{R}\ 0\right]$,

$B_{21} = [\nu\ \delta_0\ -\epsilon_1 bM\ 0\ 0]^T$ and

$$B_{22} = \begin{pmatrix} p_{11}+p_{33} & p_{34} & p_{12} & 0 & -\frac{p_{14}}{R} \\ p_{43} & p_{11}+p_{44} & 0 & \frac{p_{12}}{R} & \frac{p_{13}}{R} \\ p_{21} & 0 & p_{22}+p_{33} & \frac{p_{34}}{R} & -\frac{p_{24}}{R} \\ 0 & p_{21}R & p_{43}R & p_{22}+p_{44}+\frac{R\prime}{R} & p_{23} \\ -p_{41}R & p_{31}R & -p_{42}R & p_{32} & p_{33}+p_{44}+\frac{R\prime}{R} \end{pmatrix},$$

Now, Lozinskii measure of the matrix B is $\upsilon(B) \leq max\{g_1, g_2\}$, where $g_1 = \upsilon(B_{11}) + \| B_{12} \|$ and $g_2 = \upsilon(B_{22}) + \| B_{21} \|$. Proceeding in this manner, we would get

$$\upsilon(B) < \frac{R\prime}{R} - \overline{Y},$$

for t sufficiently large, where

$$y = min\{\frac{\gamma m\mu}{\lambda} + \frac{\epsilon_1 bm^2\mu}{\lambda} + \alpha m + \epsilon_1 bm - 2\omega,$$

$$-\gamma - \delta_0 + \epsilon_1 bm + \frac{\gamma m\mu}{\lambda} + \frac{\epsilon_1 bm^2\mu}{\lambda} + \alpha m + \mu - \frac{\epsilon_1 b\lambda}{\mu},$$

$$-\gamma - \delta_0 + \epsilon_1 bm + \frac{\gamma m\mu}{\lambda} + \frac{\epsilon_1 bm^2\mu}{\lambda} - \omega + \theta,$$

$$-\gamma - \delta_0 - \frac{\alpha\lambda}{\mu} - \frac{\alpha\lambda^2}{\mu^2} - \frac{\epsilon_1 b\delta_0\lambda^2}{\theta\mu^2} + \frac{\gamma m\mu}{\lambda} + \frac{\epsilon_1 bm^2\mu}{\lambda} - \epsilon_1 b,$$

$$-\gamma - \delta_0 - \frac{\alpha\lambda}{\mu} - \frac{\alpha\lambda^2}{\mu^2} - \frac{\delta_0\lambda}{\mu} + \theta\}$$

Let (S, I, R, M) be any solution which is emanating form Γ. Since, the system is uniformly persistent, there exists $\bar{t} > 0$, such that $(S, I, R, M) \subset \Gamma$ for all $t \geq \bar{t}$. Therefore $t \geq \bar{t}$ along every path (S, I, R, M) with $(S_0, I_0, R_0, M_0) \in \Gamma$ confirming the global stability of the epidemic system (1) about the endemic equilibrium point E^*.

Numerical Simulations

In this Section, we numerically validate our proposed epidemic model (1) with the baseline parameter values taken as $\lambda = 1000, \alpha = 0.012, \delta = 0.01, \omega = 0.5, \epsilon_1 = 0.1, \gamma = 0.01, \mu = 0.8, b = 0.04, \theta = 0.01, \delta_1 = 0.01$ and using the Matlab software. In Figure 1 and Figure 2, the global asymptotic stability of the epidemic system (1) around the disease-free equilibrium point (E_0) and the endemic equilibrium point (E^*) are portrayed respectively irrespective of initial conditions in the $S - I - M$ phase space. The figures also indicate that media awareness is necessary to decrease the level of infection.

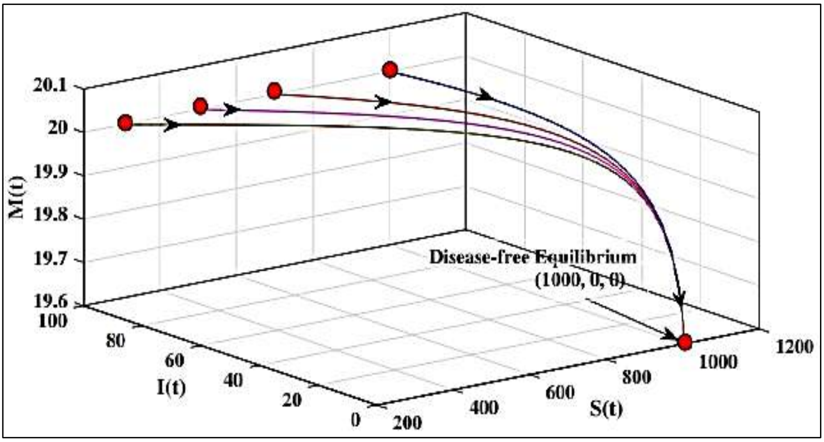

Fig 1: The figure is indicating the global asymptotic stability of the epidemic system (1) around the disease-free equilibrium $E_0(1000,0,0)$ in the *S-I-M* phase space

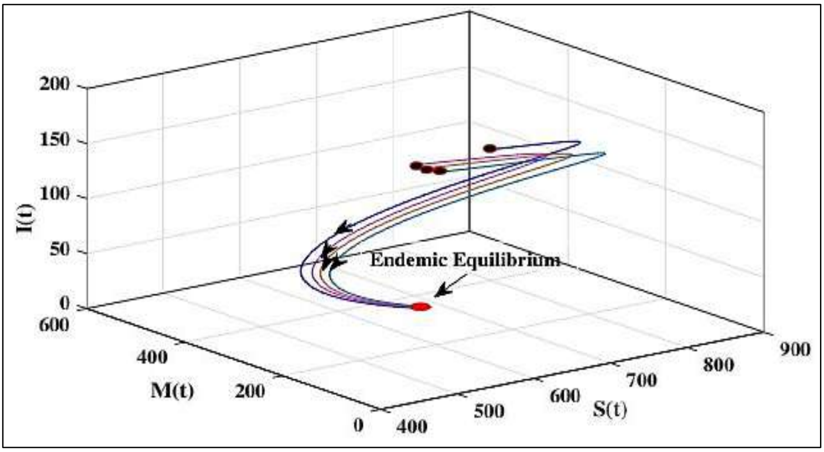

Fig 2: The figure is indicating the global asymptotic stability of system (1) around the equilibrium E* in the *S-I-M* phase space

Discussion and Conclusions

In this present article, a four-dimensional ODE deterministic model is presented to capture the role of media awareness in mitigating the global burden of typhoid fever transmission. The model is analysed both analytically and numerically. The system has one disease-free equilibrium point and one endemic equilibrium point. The global asymptotic stability of the epidemic system around the endemic equilibrium point is investigated suggesting the fact that media awareness is necessary in reducing the global burden of typhoid fever transmission.

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Chapter - 5
Synthesis of Lead Tetraphenyl Porphyrin and its Nanocomposites with Polyniline-Carbon Nanotubes-Enhanced Dielectric Properties

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Chapter - 5

Synthesis of Lead Tetraphenyl Porphyrin and its Nanocomposites with Polyniline-Carbon Nanotubes-Enhanced Dielectric Properties

Shilpa Maity

Abstract

Lead tetraphenyl porphyrin (PbTPP) and its nanocomposite with polyaniline-carbon nanotubes (PANI-CNT) were prepared by simple dissolving technique. The structural properties of both the samples were investigated by using x-ray diffraction technique. Dielectric properties and ac conductivity of both the samples have been studied in the temperature range 313-403 K at a fixed frequency 100 Hz. Values of the dielectric constant $\varepsilon' \varepsilon'$ and dielectric loss ε" were found to increase with the increase in temperature. The maximum value of the dielectric constant of PbTPP-PANI-CNT is 1319 which is 20 times higher than previous report. In the present paper the dielectric behavior of lead tetraphenyl porphyrin (PbTPP) and its composite with polyaniline-carbon nanotubes (PANI-CNT) are reported.

Keywords: Lead tetraphenyl porphyrin (PbTPP), nanocomposite, dielectric constant, dielectric loss, AC conductivity

Introduction

Dielectric materials with improved properties have been in the area under discussion in recent days with varied applications in industrial devices such as voltage-controlled oscillators and telecommunication technologies [1]. The group of organic molecules with conjugated electron systems further widens the possibility of advanced claims in many modern applications [2] including dielectrics. Porphyrins are highly conjugated systems composed of four pyrrole subunits interlocked at their α carbon atoms via methane bridges (=CH-) [3]. Almost all metals have been coordinated to the porphyrins. Further, the synthesis of polymer carbon nanotubes (CNT) composites provides synergetic or complementary behaviors between the polymer and CNTs. Polyaniline is a most studied conducting polymer because of its relative ease in preparation, good environmental stability and tunable conductivity [4].

In the present paper the dielectric behavior of lead tetraphenyl porphyrin (PbTPP) and its composite with polyaniline-carbon nanotubes (PANI-CNT) are reported. The aim of this paper is to study the influence of PANI-CNT on the ac conductivity and dielectric properties of PbTPP. To the best of our knowledge, for the first time the study of ac conductivity and dielectric properties of PbTPP and its nanocomposites with PANI-CNT has been reported.

Experimental

Aniline monomer of general grade was purchased from Fisher Scientific India, Ammonium persulphate (APS), Ethanol, Benzaldehyde, Pyrrole, Propionic acid, Dimethyl Formamide (DMF) and lead acetate ($Pb(OCOCH_3)_2$) were purchased from Merck chemicals. Deionised water was purchased from Hydrolab, India. Single-walled carbon nanotubes (SWNTs) was purchased from US Research Nanomaterials, Inc. Propionic acid is added to a round bottom flask with a reflux condenser and is heated to a strong reflux. Then a mixture consisting of pyrrole and benzaldehyde is added through the condenser and the mixture is heated at reflux until it turns blood red. The solution is then cooled and the porphyrin (H_2TPP) product was washed with methanol until it is colorless and then the product is air dried. Then a mixture of porphyrin (H_2TPP), DMF and $Pb(OCOCH_3)_2$ is ultrasonicated for 10 min and kept for reflux over the course of 2 hours. The synthesized product (PbTPP) was washed with deionised water and ethanol and vacuum dried. PANI-CNT composites was synthesized as stated in literature [5] with 10 wt% of CNT content within the matrix of PANI. For the synthesis of PbTPP-PANI-CNT, equal amount of PbTPP and PANI-CNT nancomposite were dispersed in 100 ml chloroform with 10% methanol followed by 10 min of ultrasonication at 45 ^oC. In this process, PbTPP and PANI-CNT nanocomposites are expected to interact at molecular level. The solution is then kept in a round buttom flux and with rotary evaporator the solvent is evaporated and pure sample of PbTPP-PANI-CNT nanocomposites was obtained.

Characterization

The synthesized samples PbTPP and PbTPP-PANI-CNT were structurally characterized by powder x-ray diffraction (XRD) recorded by D8

Bruker AXS, Wisconsin, USA with a Cu Kα radiation (λ = 1.5418 Å). The surface morphology of the samples was investigated by using field emission scanning electron microscopy (FESEM) (FEI, INSPECT F50). All the prepared samples were pressed at room temperature using peletizer and cut into small circular pellets for measuring the dielectric properties. The capacitance C_p and loss factor ($\tan\delta$) was measured by a programmable automatic LCR meter (Agilent, E4980A) directly at a fixed frequency (100 Hz) with an osciliation level of 100 mV. The pellets were taken under a dark condition using a specially designed holder for measuring the dielectric properties and the temperature was switched with a programmable oven with temperature range from 313 K to 403 K with accuracy of about $\pm$ 2 K. The dielectric constant, dielectric loss and the ac electrical conductivity is given by

$$\varepsilon' = (C \bullet d)/(\varepsilon_0 \bullet A) \quad (1)$$

$$\varepsilon'' = \varepsilon' \tan\delta \quad (2)$$

$$\sigma_{ac} = 2\pi f \varepsilon_0 \, \varepsilon'' \quad (3)$$

Where C, d, A and $\tan\delta$ are the capacitance, thickness, effective area, loss factor of the samples and ε_0 = 8.805 x 10^{-12} F m^{-1}, is the free space permittivity. The values of the dielectric constant, dielectric loss and ac conductivity (σ_{ac}) of the samples were evaluated using above equations.

Result and Discussion

The XRD patterns of samples are shown in figure 1. Many peaks with different intensities have been observed from the spectra which indicate that the materials are polycrystalline in nature. Distinct peaks of PANI and CNT are also observed from the spectrum of PbTPP-PANI-CNT nanocomposite.

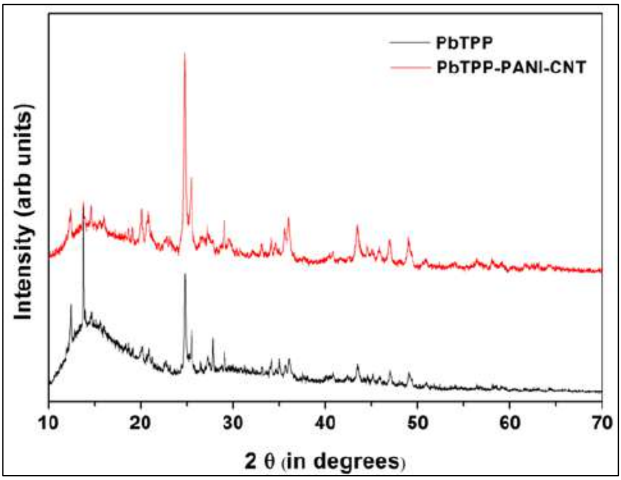

Fig 1: XRD Spectra of PbTPP and PbTPP-PANI-CNT Nanocomposite

Figure 2 illustrates the SEM morphology of the as synthesized samples. The presence of PANI-CNT was confirmed from the morphology which is in tune with the XRD spectra.

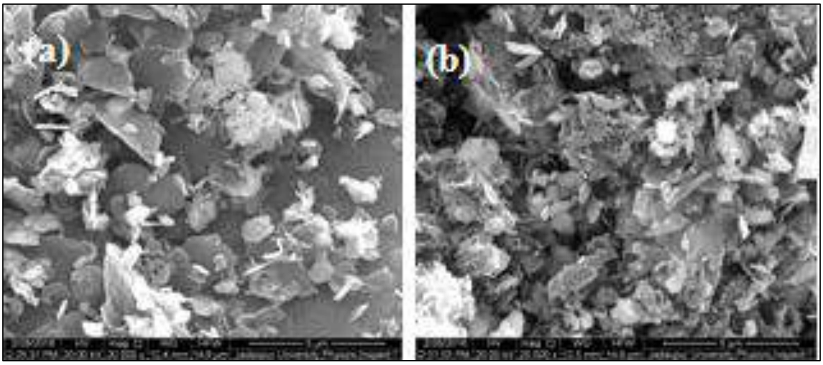

Fig 2: SEM images of PbTPP and PbTPP-PANI-CNT Nanocomposite

4.1 Temperature Dependence of Dielectric Constant and Dielectric Loss

Dielectric analysis of materials predicts the insulating nature, representing its capacity to store electric charge and the conductive nature, indicating its ability to pass electronic charge. Dielectric constant (ε') of the samples as a function of temperature at fixed frequency (100 Hz) is shown in figure 3. It is observed that ε' increases with increase in temperature at constant frequency. This can be attributed as follows.

At low temperature the dipoles cannot orient themselves as the orientational polarization is linked with the thermal motion of molecules. The increase in temperature facilitates the orientation of dipole which in turn increases the orientational polarization. As a result ε' increases with increase in temperature. The maximum value of the dielectric constant of PbTPP-PANI-CNT is 1319 which is 20 times higher than previous report.

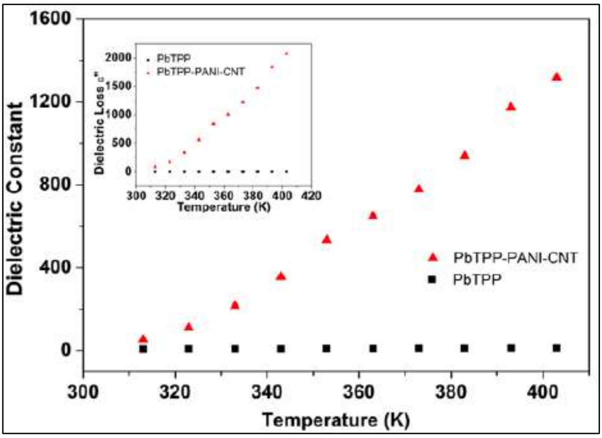

Fig 3: Temperature variation of dielectric constant of the prepared samples. Inset shows the temperature variation of dielectric loss of the prepared samples

The temperature dependence of the dielectric loss (ε") for both the samples are shown in the inset of figure 3. It is observed that the ε" value increases with the increase in temperature. The dielectric loss can be separated into three parts: conduction losses, dipole losses, and vibrational losses. Conduction loss involves the migration of ions over large distances. During this migration, a part of their energy is transmitted to the lattice as heat which is proportional to $\sigma_{ac}(\omega)/\omega$. The conduction losses have minimum value at low temperature but with the increase in temperature $\sigma_{ac}(\omega)/\omega$ increases and consequently the conduction loss increases. This leads to increase of the value of dielectric loss with temperature.

Temperature Dependence of AC Conductivity

Figure 4 shows the temperature dependence of $\sigma_{ac}(\omega)$ at a fixed frequency 100 Hz for both the samples which increase with the increase in temperature. Inset of figure 4 shows the variation of ln σ_{ac} against 1000/T. The ac conductivity is expressed as $\sigma = \sigma_0 \exp(\Delta E/kT)$ where σ_0 is the pre-exponential factor, ΔE is the apparent activation energy and k is the

Boltzmann constant. The figure indicates that ΔE value is more for PbTPP-PANI-CNT than PbTPP. This indicates that the hopping mechanism of conduction is weak for PbTPP-PANI-CNT.

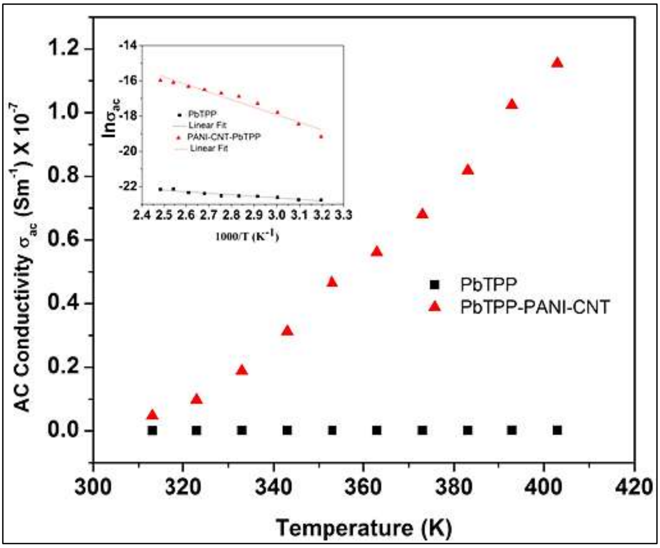

Fig 4: Temperature dependence of AC conductivity of the prepared samples. Inset shows the variation of ln σ_{ac} against 1000/T of the prepared samples

Conclusion

PbTPP and its nanocomposites with PANI-CNT has been synthesized by simple dissolving method. The XRD spectra indicates that both the samples are polycrystalline in nature. Further the presence of PANI-CNT has also been confirmed which is in tune with the SEM images. For both the samples, dielectric constant (ε') and dielectric loss (ε") are found to increase with increase in temperature at a fixed frequency 100 Hz. The maximum value of dielectric constant is 1319 for PbTPP-PANI-CNT composite which is higher than any porphyrin-based materials. The temperature dependence of ac conductivity also shows an increase with temperature. The values of activation energy ΔE, as evaluated, suggest that the hopping conduction is lower for the composite.

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Chapter - 6
A Short Review on Magnetic Property of Nanosized Cobalt-Zinc Ferrites

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Chapter - 6

A Short Review on Magnetic Property of Nanosized Cobalt-Zinc Ferrites

Subhrajyoti Dey

Abstract

Cobalt-zinc ferrite nanoparticle system have been considered as an important system for the study of the origin of different types of magnetic phase in ferrimagnetic material. For spinel ferrites, the oxygen mediated exchange interactions (J_{AA}, J_{BB} and J_{AB}) between magnetic ions in tetrahedral (A) and octahedral [B] sites plays a crucial role in determining the magnetic ordering of the system. The relative distribution of magnetic and non-magnetic cations among (A) and [B] sites influences the strength of exchange interaction in the system. $CoFe_2O_4$ displays inverse spinel structure where the interaction between (A) and [B] site Fe^{3+} ions are very strong. On the other hand $ZnFe_2O_4$ is normal spinel in nature and the interaction between (A) and [B] site Fe^{3+} ions is generally very weak. The literature review suggests the incorporation of non-magnetic zinc ion into cobalt ferrite system leads to diverse magnetic properties like non-collinear spin structure, spin glass like behavior, antiferromagnetism etc. In this background the aim of the present review is to study the different synthesis techniques to synthesize nanosized cobalt-zinc ferrite and their magnetic property available in literature.

Introduction

For the last few decades nanosized spinel ferrites fostered enormous enthusiasm in the field of research of material science due to their multifaceted application possibilities in diverse technological arenas like targeted drug delivery, hyperthermia treatment, magnetic resonance imaging, electrochemical method-based bio-sensors, gas sensing, microwave devices, supercapacitors, high density recording media, catalysis [1-10]. Spinel ferrites possesses AB_2O_4 type general formula, where A and B represents divalent and trivalent cations, respectively. Two types of crystallographic sites, tetrahedral (A) and octahedral [B] sites are present in the crystal structure of ferrites. (A) sites are generally occupied by divalent metal cations, whereas the [B] site is usually occupied by trivalent cations. Depending upon the distribution of divalent and trivalent metal ions among the tetrahedral (A) and octahedral [B] sites, ferrites are broadly classified as normal and inverse spinel. $ZnFe_2O_4$ has a normal spinel structure which can be represented as $(Zn^{2+})_A$ $[Fe^{3+}{}_2]_B$ O_4, where all the trivalent iron cations resides at octahedral [B] site. On the other hand, $CoFe_2O_4$ is an well-known example of inverse spinel structure where Fe^{3+} ions are equally distributed between (A) and [B] sites as $(Fe^{3+})_A$ $[Co^{2+}Fe^{3+}]_BO_4$. The mixed spinel structures are represented by $(M_{1-x}{}^{2+}Fe_x{}^{3+})_A$ $[M_x{}^{2+}Fe_{2-x}{}^{3+}]_BO_4$, when $0 < x < 1$ and M represents the metallic ion [11].

In case of spinel ferrites, the magnetic interaction between neighboring cations is mainly controlled by super exchange interaction which is monitored by an intermediate oxygen anion. As proposed by the super exchange theory for cations with half or more than half occupied 3d electronic configuration, the exchange energy in spinel type ferrite is negative. Trivalent ferric ion (Fe^{3+}) and divalent transition metal ions (like Co^{2+}, Zn^{2+}) satisfies the above-mentioned condition and can be easily substituted in spinel ferrite structures. The strength of the super exchange interaction depends on the separation distance amid the magnetic cations and the oxygen ion and it has been reported that the interaction weakens with the increase of separation. In addition, the super exchange interaction is also dependent upon the angle between the magnetic cations and the oxygen anion and the super exchange theory predicts the strongest interaction at an angle of 180° [12-14].

Spinel ferrites crystallize in face centered cubic crystal system having fd-3m space group. The oxygen ions form a cubic close-packed arrangement with metal cations filling the interstitial sites. In every unit cell there are two kinds of interstitial sites, 64 tetrahedral (A) sites and 32 octahedral [B] sites which are surrounded by 4 oxygen ions and 6 oxygen anions, respectively [15]. Generally, 1/8 of (A) sites and 1/2 of [B] sites are occupied by metal ions which suggests that each unit cell contains 8 and 16 metal ions at tetrahedral and octahedral sites, respectively. It is widely accepted that the magnetic properties of nano ferrites is directly linked to the selection of cations and there comparative distribution between the tetrahedral (A) and the octahedral [B] sites of the spinel lattice [11].

As mentioned earlier, the exchange interactions between magnetic ions in ferrites are mediated by oxygen anions and the exchange integrals J_{AA}, J_{BB} and J_{AB} are associated with the exchange interaction between cations of tetrahedral (A) sites, the exchange interaction among cations of octahedral (B) sites and the exchange interaction between cations in tetrahedral (A) sites and cations in octahedral (B) sites, respectively. Commonly, for spinel ferrites, the exchange integrals J_{AA}, J_{BB} and J_{AB} are negative suggesting the presence of antiferromagnetic interaction [11]. The J_{AB} integral involving interaction between cations of (A) and [B] sites via an oxygen anion is significantly stronger compared to the J_{AA} and J_{BB} integrals concerning the interaction among the cations of the same interstitial sites [11]. The superiority of J_{AB} interaction results in antiparallel arrangement of the spins of dissimilar (A) and [B] sublattice which leads to frustration in the system as the spin orientation in dissimilar sublattices cannot instantaneously satisfy all exchange interactions [11]. If all the (A) and [B] site sublattices are occupied by magnetic cations, then we can observe a non-compensated magnetic moment which is the characteristic feature of ferrimagnetic ordering. Earlier it was observed that the replacement of magnetic cations leads to the reduction of magnetization of the system which was attributed to the non collinear spin structure or spin canting effect [16]. Further dilution of magnetic ions through incorporation of nonmagnetic cations may lead to a range of striking magnetic behaviors like spin glass like behavior, canted ferrimagnetism, antiferromagnetism etc [11, 13, 16-18]. The detail review study of the magnetically diluted nanostructured ferrites appears to be very promising for their application in various technologies.

$CoFe_2O_4$ displays inverse spinel structure where divalent cobalt ions occupy the octahedral [B] sites and the trivalent Fe ions are equally distributed among the tetrahedral (A) and octahedral [B] sites. Thus the interaction between (A) and [B] site Fe^{3+} ions are very strong which leads to ferrimagnetic ordering in $CoFe_2O_4$ below 790 K (T_N) [11]. On the other hand, $ZnFe_2O_4$ is normal spinel and all the Fe^{3+} ions generally reside at the [B] sites. Thus the Fe_A–O–Fe_B interaction is not effective here due to the absence of magnetic cation at the (A) sites. Only antiferromagnetic ordering is effective here due to the interaction of [B] site iron ions and the T_N of $ZnFe_2O_4$ is only 9 K [12]. The incorporation of zinc ions in cobalt ferrite leads to the migration of iron ions from (A) to [B] sites which reduces the strength of Fe_A–O–Fe_B interaction. The structural formula for the zinc substituted cobalt ferrite is given by $(Zn_{1-x}Fe_x)_A$ $[Co_xFe_{2-x}]_B$ O_4. As mentioned earlier, zinc substitution leads to a range of striking magnetic behaviors like spin glass like behavior, canted ferrimagnetism, antiferromagnetism etc in Co-Zn ferrites. In addition to theses, at nanoscale spin canting effect and cation redistribution among the (A) and [B] site also plays a crucial role in determining the magnetic property of the system [19-22].

Due to their ability to exhibit a range of interesting magnetic properties stemming from the complex interplay between different types of exchange interactions along with the effects of nanometric size, Co-Zn ferrites are undoubtedly considered as a fascinating system to study the physical origins of several types of magnetic phases in ferrimagnetic materials. In this short review we have discussed and compared the magnetic properties of nanosized zinc substituted cobalt ferrite systems.

Synthesis Technique

It is well known that the synthesis technique of Co-Zn ferrite significantly influence their nanoscale physical and chemical properties. Every preparation technique has its own set of advantages and disadvantages. Material scientists make the choice of synthesis method depending on the desired physico-chemical properties of the material including particle size, shape, morphology etc. Many research groups have reported diverse synthesis techniques to synthesize $Co_{1-x}Zn_xFe_2O_4$ nanoparticles, some of which are discussed below for examples.

Co-precipitation method is a well-known synthesis technique of iron based magnetic nano particles in aqueous medium. Andhare *et al*. have synthesized $Co_{1-x}Zn_xFe_2O_4$ with x = 0, 0.3, 0.5, 0.7, 1 nanoparticles with crystallite size of 12, 13, 15, 16 and 17 nm, respectively by coprecipitation method keeping pH of the solution at 11 [23]. Urcia-Romero *et al*. synthesized nanocrystalline $Co_{1-x}Zn_xFe_2O_4$ (x = 0.5, 0.2 and 0.1) of sizes 11, 17 and 18 nm, respectively by a novel flow rate controlled coprecipitation method and Dey *et al*. synthesized $Co_{0.2}Zn_{0.8}Fe_2O_4$ (~ 20 nm) by flow rate controlled coprecipitation method at medium pH of the reactant solution (pH–10) [24, 11]. Microwave assisted combustion method have been used by Koseoglu *et al*. to synthesize $Co_{1-x}Zn_xFe_2O_4$ (x = 0.8, 0.4, 0.2) and Parmer *et al*. to synthesize $Co_{0.5}Zn_{0.5}Fe_2O_4$ (~ 41 nm) nanoparticles [25, 26]. Fan *et al*. have reported the synthesis of $Co_{1-x}Zn_xFe_2O_4$ (x = 0.9, 0.8, 0.6) having sizes 12, 11 and 27 nm, respectively by a facile oxidation-reduction method through hydrothermal technique [27]. $Co_{1-x}Zn_xFe_2O_4$ nanoprticles with size ranging between 11-28 nm with x = 0.3, 0.8, 0.1 etc. have been synthesized by sol-gel method [28]. Nanosized $Co_{1-x}Zn_xFe_2O_4$ (x = 0.1, 0.3, 0.5, 0.7) of average crystallite size 17, 15, 11 and 9 nm have been synthesized by hydrothermal method [29]. Ding *et al*. have synthesized $Co_{0.6}Zn_{0.4}Fe_2O_4$ nanoprticles having size ranging between 9.9 to 27 nm by different hydrothermal methods [30]. High energy ball milling or mechanochemical synthesis route is also a celebrated technique for the synthesis of Co-Zn ferrite nanoparticle system and several reports are available regarding synthesis and characterization of nanometric $Co_{1-x}Zn_xFe_2O_4$ [19-22, 31, 32]. Yadav *et al*. have synthesized nanosized $Co_{0.5}Zn_{0.5}Fe_2O_4$ nanoprticles by starch assisted solgel auto combustion method followed by high energy ball milling [33]. Chen *et al*. have synthesized nanosized $Co_{1-x}Zn_xFe_2O_4$ (0.2, 0.5, 0.8) having average particle size 10-15 nm by microwave assisted ball milling method [34].

It is well established that the nanoscale magnetic property of spinel ferrite is strongly influenced by its structural and microstructural parameters like size, shape, morphology, amount of lattice strain, relative distribution of cations among the tetrahedral (A) and octahedral [B] sites of the spinel lattice which in turn also is governed by the synthesis technique and reaction parameters. From the above small discussion on different synthesis routes of nanosized Co-Zn ferrite it is clear that the proper choice of synthesis route and maintaining the reaction condition at some optimized condition can deliver nanosized ferrite of specific shape and size which can help us to tailor the nanoscale magnetic property of the systems.

Magnetic Property

The introduction of non-magnetic ions by replacing magnetic cations in tetrahedral (A) and octahedral [B] site of spinel lattice modifies the prevailing intra and inter sublattice exchange interaction which leads to diverse type of remarkable magnetic phenomena [31]. Throughout the time, zinc substituted cobalt ferrite nanoparticles systems have been considered as one of the most interesting system to study the origin of different magnetic phases as magnetic dilution through zinc substitution have shown to develop diverse type of magnetic character like non-collinear spin structure, spin glass like behavior, canted ferrimagnetism, antiferromagnetism etc. in the system [31]. In addition to these, finite size effect, spin canting effect and cation redistribution play important role to modify the nanoscale magnetic property of spinel ferrites [31]. Here we have compared the magnetic property of some nanosized $Co_{1-x}Zn_xFe_2O_4$ systems synthesized by different techniques.

DC magnetic property study provides valuable information regarding the magnetic property of the material under investigation and its response towards external magnetic field and temperature. Vibrating sample magnetometer (VSM) and superconducting quantum interference device magnetometer (SQUID) are generally used to characterize the magnetic property of a material. The variation of magnetization as a function of temperature at some constant value of external magnetic field is generally recorded using zero field cooled (ZFC) and field cooled (FC) protocol experiments. The dependence of magnetization over the externally applied magnetic field (hysteresis loop study) at some constant temperature is generally measured under ZFC mode.

Table 1: Comparison of magnetic property of nanosized $Co_{0.2}Zn_{0.8}Fe_2O_4$

Synthesis Technique	Crystallite Size (nm)	Saturation Magnetization (emu/g)	Coercivity (Oe)	Blocking Temperature (K)	Ref.
Flowrate controlled co-precipitation method at pH 10	20	32 (300 K) 39.5 (50 K)	0 (300 K) 200 (50 K)	70 (500 Oe)	[11]
Microwave assisted ball milling technique	10-15	21.02 (300 K)	116 (300 K)	-	[34]
Microwave assisted combustion method	39.1	11.5 (300 K) 64.32 (10 K)	0 (300 K) 2800 (10 K)	127 (100 Oe)	[25]
Reduction-oxidation method	11	14 (300 K)	0 (300 K)	-	[27]
Flow rate controlled coprecipitation method followed by ball milling	18	44 (300 K) 85 (10 K)	0 (300 K) 2800 (10 K)	220 (100 Oe) 190 (500 Oe)	[31]
Mechanical alloying	21	40 (10 K)	4500 (10 K)	280 (30 Oe)	[19]
High energy milling of bulk sample	20	80 (10 K)	>2000 (10 K)	320 (30 Oe) 280 (100 Oe)	[32]

Table 2: Comparison of magnetic property of nanosized $Co_{0.3}Zn_{0.7}Fe_2O_4$

Synthesis Technique	Crystallite Size (nm)	Saturation Magnetization (emu/g)	Coercivity (Oe)	Blocking Temperature (K)	Ref.
Co-precipitation method	30	27.4 (300 K) 46.5 (5 K)	0 (300 K) 5000 (5 K)	145 (100 Oe)	[20]
Co-precipitation followed by ball milling technique	16.6	59 (300 K) 88 (5 K)	0 (300 K) 3000 (5 K)	220 (100 Oe) 180 (500 Oe)	[20]
Coprecipitation method	14	22 (300 K)	0 (300 K)	133 (100 Oe)	[35]

with temperature treatment		75 (4.5 K)	8168(4.5K)		
Chemical coprecipitation method followed by hydrothermal method at pH 10.5	5.5 5.9 8.3	6 (300 K) 10 (300 K) 17 (300 K)	0 (300 K) 0 (300 K) 0 (300 K)	58 (50 Oe) 73 (50 Oe) -	[36]
Chemical coprecipitation method followed by hydrothermal method at pH 11.6	6.8 7.3 9.0	13 (300 K) 19 (300 K) 28 (300 K)	0 (300 K) 0 (300 K) 0 (300 K)	98 (50 Oe) 115 (50 Oe) -	[36]

Table 3: Comparison of magnetic property of nanosized $Co_{0.5}Zn_{0.5}Fe_2O_4$

Synthesis Technique	**Crystallite Size (nm)**	**Saturation Magnetization (emu/g)**	**Coercivity (Oe)**	**Blocking Temperature (K)**	**Ref.**
Co-precipitation method	51	82 (300 K)	75.4(300K)	-	[37]
Co-precipitation followed by ball milling for 3, 6, 9 hours	63 25 17	56.8 (300 K) 55.3 (300 K) 51.5 (300 K)	30 (300 K) 20 (300 K) 0 (300 K)	220 (100 Oe) 210 (100 Oe) 204 (100 Oe)	[21]
Sol-gel auto combustion method	29.01	90.13 (300 K)	176(300 K)	-	[38]
Solution combustion method	12	63 (300 K)	100(300 K)	-	[39]
Microwave combustion method	35.68	73.8 (300 K)	300 (300K)	-	[40]
Sol-gel method	23.1	73.6 (300 K)	314 (300K)	-	[41]
Hydrothermal	11.2	56.7 (300 K)	1464(300K	-	[41]

Table 4: Comparison of magnetic property of nanosized $Co_{0.8}Zn_{0.2}Fe_2O_4$

Synthesis Technique	**Crystallite Size (nm)**	**Saturation Magnetization (emu/g)**	**Coercivity (Oe)**	**Blocking Temperature (K)**	**Ref.**
co-precipitation afterward ball milling and heat treatment	23 34 42	75.22 (300 K) 81.07 (300 K) 82.89 (300 K)	530(300 K) 460(300 K) 420(300 K)	300 (500 Oe) 300 (500 Oe) 300 (500 Oe)	[22]
Sol-gel auto combustion method	43.93	55.947 (300 K)	306(300 K)	-	[42]
Microwave combustion method	37.5	59 (300 K)	117(300 K)	> 300 K	[25]
Microwave assisted ball milling	10 – 15	85.93 (300 K)	316.89	-	[34]
Coprecipitation method	30 - 50	74 (300 K)	-	-	[43]

From the above examples it is clear that the magnetic property of nanosized $Co_{1-x}Zn_xFe_2O_4$ not only depends upon the relative concentration of cobalt and zinc cation in the spinel lattice, but also very much sensitive to the synthesis route which controls shape, size, morphology of the system which further plays a crucial role in determining the magnetic property of the system.

Conclusion

In this short review we have discussed about different conventional synthesis technique of nanosized $Co_{1-x}Zn_xFe_2O_4$ and through literature review have given some examples to show that selection of synthesis route is crucial for determination of structural and microstructural parameter of the system. The review also discussed about the available reports on the magnetic property of nanosized $Co_{1-x}Zn_xFe_2O_4$ which is very much sensitive to the synthesis technique that further determines the shape, size, morphology, relative cation distribution in (A) and [B] site of the system.

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Chapter - 7
Higher-Order Evolution Equation for Broader Bandwidth Capillary-Gravity Waves in the Presence of Depth Uniform Current

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Chapter - 7

Higher-Order Evolution Equation for Broader Bandwidth Capillary-Gravity Waves in the Presence of Depth Uniform Current

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Abstract

The study of a higher-order evolution equation for capillary-gravity waves, considering a broader bandwidth of wave components and the influence of a uniform current. Capillary-gravity waves, which arise from the interplay of surface tension and gravity, often exhibit complex behavior that can be significantly impacted by uniform currents in the fluid. Traditional models typically focus on narrow bandwidths and simplified current effects, which can limit their accuracy in practical scenarios. The proposed higher-order evolution equation extends these models by incorporating a wider range of wave frequencies and accounting for the effects of a uniform current throughout the water column. This approach provides a more accurate representation of wave dynamics, capturing how the current modifies wave amplitudes, frequencies, and phase speeds across different scales. Through perturbation techniques and multiscale methods, this model addresses the limitations of previous approaches and offers insights into the interaction between capillary forces, gravity, and the current. The enhanced model is valuable for applications in coastal and offshore engineering, where understanding wave behavior under varying current conditions is crucial. The findings highlight the importance of considering higher-order effects and broader bandwidths for precise wave prediction and management in real-world environments.

Keywords: Nonlinear evolution equation, capillary-gravity waves, broader bandwidth, modulational instability

Introduction

In the studies of the nonlinear evolution of deep-water waves, nonlinear Schrödinger equation (NLSE) is generally used as it can properly reflect the sideband instability, that is, the Benjamin-Feir instability. In general, capillary-gravity waves are generated by wind which produces a shear flow in the topmost layer of the water and as a result these waves move in the presence of vorticity. These waves play a momentous role in the development of wind waves, contribute partially to the ocean surface stress and therefore take part in ocean-sea momentum transfer. Proper representation of the surface stress is useful in modelling and predicting sea wave dynamics. The instability of finite amplitude capillary-gravity waves has been studied by many authors. Djordjevic and Redekopp [1] and Hogan [2] have investigated cubic nonlinear envelope equations for finite and infinite depths of water respectively and studied the sideband instability (Benjamin-Feir instability) of progressive capillary-gravity waves. Dhar and Das [3] have investigated the fourth-order nonlinear evolution equation (NLEE) for two surface capillary-gravity waves on deep water and stability analysis is then presented for two Stokes waves. Debsarma and Das [4] have also derived two coupled fourth-order NLEEs in deep water including the effect of thin thermocline for capillary-gravity waves. After reducing these two equations to a single equation in the case of oblique plane wave perturbation, they have studied the stability analysis for a uniform wave train. Although the stability analysis made from fourth-order NLSE gives excellent results compared to the third-order equation, the limitation in wave bandwidth severely restricts the applicability of third- and fourth-order Schrödinger equations for three-dimensional sea waves in two ways. First, the ocean wave spectra from the continental shelf are often bandwidth restricted but have bandwidths exceeding the above restriction. Second, these evolution equations have instability regions for a finite amplitude wave extending outside the narrow bandwidth constraint. Keeping this view, Trulsen and Dysthe [5] have derived a higher-order NLEE for the broader bandwidth surface gravity waves on deep water in which the wave bandwidth and nonlinearity have been considered as $O\left(\epsilon^{1/2}\right)$ and $O(\epsilon)$ respectively. Following Trulsen and Dysthe [5], we take finite depth, deep water, and infinite depth as $(kh)^{-1}$ being $O(1), O(\epsilon)$ and 0 respectively.

According to Trulsen and Dysthe [5], one avenue of interest is to include some new linear terms to the fourth-order NLEE derived by Dysthe [6], which have increased considerably the resolution in spectral bandwidth. In this paper, we extend the analysis of Trulsen and Dysthe [5] to include the effect of capillarity. The objective and the novelty of this paper is to derive a new higher-order NLEE for a broader bandwidth and to develop a weakly nonlinear theory of the periodic capillary-gravity waves on finite depth of water under the action of Depth Uniform Current (DUC).

The Governing Equations and the Fourth-Order Evolution Equation

We adopt the geometric setup of a Cartesian coordinate frame (Oxyz), where z axis is directed upward in the opposing direction of gravity g. In this framework, the undisturbed free surface is represented by z=0, while the disturbed free surface is represented by z=ζ(x,y,t). We suppose that the waves flow steadily on a DUC v, where v denotes the speed of the current at the free surface and moves in the positive direction of the x axis. For describing the irrotational motion of gravity waves on the surface of deep water, we take the following governing equations into consideration:

$$\nabla^2\phi = 0 \text{ in } -h < z < \zeta(x,y,t) \tag{1}$$

$$\phi_z - \zeta_t - v\zeta_x = \phi_x\zeta_x + \phi_y\zeta_y \text{ at } z = \zeta \tag{2}$$

$$\phi_t + v\zeta_x + \zeta = -\frac{1}{2}(\nabla\phi)^2 + \kappa\frac{(\zeta_x^2\zeta_{yy}+\zeta_y^2\zeta_{xx}-2\zeta_x\zeta_y\zeta_{xy}+\zeta_{xx}+\zeta_{yy})}{(1+\zeta_x^2+\zeta_y^2)^{\frac{3}{2}}} \text{ at } z = \zeta \tag{3}$$

$$\text{Also } \phi_z = 0, \text{ at } z = -h \tag{4}$$

Where $\phi(x,y,z,t)$ is the velocity potential of waves, $\zeta(x,y,t)$ is the undulating free surface, ρ is the density of fluid and $\nabla \equiv \left(\frac{\partial}{\partial x}, \frac{\partial}{\partial y}, \frac{\partial}{\partial z}\right)$. The above equations have been made dimensionless by the following transformations

$$\tilde{\phi} = \sqrt{\frac{k_0^3}{g}}\phi, \tilde{\zeta} = k_0\zeta, (\tilde{x},\tilde{y},\tilde{z}) = (k_0x, k_0y, k_0z), \tilde{t} = \omega t, \kappa = \frac{Tk_0^2}{\rho g},$$

Where k_0 is some characteristic wavenumber, g is the gravitational acceleration and T is the surface tension coefficient of the bulk fluid. In subsequent analysis, all these dimensionless quantities will be written with their tilde deleted.

The solutions of the above-mentioned equations can be expressed as

$$\mathrm{B} = \overline{\mathrm{B}} + \sum_{\mathrm{p}=1}^{\infty}\left[\mathrm{B_p}\exp\{(\mathrm{ip}(\mathrm{kx} - \omega\mathrm{t}))\} + \mathrm{c.c.}\right] \tag{5}$$

Where B indicates ϕ, ζ; $c.c.$ means complex conjugate and k, ω are the wavenumber and frequency of the primary wave respectively. Here, the slow drift $\bar{\phi}$ and set down $\bar{\zeta}$ as well as the harmonic amplitudes ϕ_p, ζ_p $(p = 1, 2, \dots)$ and their complex conjugates are functions of the slow modulation variables $\epsilon x, \epsilon y$ and ϵt, where ϵ is a slow ordering parameter. Again, $\bar{\phi}$ depends on the slow variable ϵz, while ϕ_p $(p = 1, 2, \dots)$ and their complex conjugates are the function of z. We consider the fourth-order NLEE for narrow bandwidth when the motion is weakly nonlinear, so that $0 < \epsilon \ll 1$ subject to the assumption as follows

$$\mathrm{k}_0 \mathrm{a} = \mathrm{O}(\epsilon), \frac{|\nabla \mathbf{k}|}{\mathrm{k}_0} = \mathrm{O}(\epsilon), (\mathrm{k}_0 \mathrm{h})^{-1} = \mathrm{O}(\epsilon)$$

The linear dispersion relation with $l = 0$ is given by

$$f(\omega, k, l) = \omega^2 - \sqrt{k^2 + l^2}\{1 + \kappa(k^2 + l^2)\} = 0$$

Where ω, k represent the carrier frequency and wave number respectively.

By a standard procedure (Dhar and Das [7]) we obtain the fourth-order coupled NLEEs for the free surface elevation ζ, where $\zeta = \zeta_{11} + \epsilon\zeta_{12}$, and $\bar{\phi}$ as follows

$$i\left(\frac{\partial \zeta}{\partial \tau} + c_g \frac{\partial \zeta}{\partial x}\right) - \gamma_1 \frac{\partial^2 \zeta}{\partial x^2} + \gamma_2 \frac{\partial^2 \zeta}{\partial y^2} + i\left(\gamma_3 \frac{\partial^3 \zeta}{\partial x^3} + \gamma_4 \frac{\partial^3 \zeta}{\partial x \partial y^2}\right) = \mu_1 |\zeta|^2 \zeta^* + i\left(\mu_2 |\zeta|^2 \frac{\partial \zeta}{\partial x} + \mu_3 \zeta^2 \frac{\partial \zeta^*}{\partial x}\right) + \zeta \frac{\partial \bar{\phi}}{\partial x} \quad (6)$$

$$\nabla^2 \bar{\phi} = 0 \text{ for } -h < z < 0 \quad (7)$$

$$\frac{\partial \bar{\phi}}{\partial z} = 2\frac{\partial}{\partial x}(|\zeta|^2) \text{ for } z = 0 \quad (8)$$

$$\frac{\partial \bar{\phi}}{\partial z} = 0 \text{ for } z = -h \quad (9)$$

For $\kappa = 0$ and $v = 0$ the equation (6) is identical to an equation (10) of Trulsen and Dysthe [5].

Typically, one assumes that the wave steepness and the bandwidth are of the identical order of magnitude $O(\epsilon)$, for which both the nonlinear and dispersive effects balance at the fourth order $O(\epsilon^4)$.

Stability Analysis

A solution for the uniform wave train of the NLEE is given by

$$\zeta = \frac{\zeta_0}{2} e^{-i\mu_1 \zeta_0^2 t/4}, \bar{\phi} = \phi_0,$$

Where ζ_0, ϕ_0 are real constants.

We assume the perturbations on this solution as follows

$$\zeta = \frac{\zeta_0}{2}(1 + \zeta') e^{i(\theta' - \mu_1 \zeta_0^2 t/4)}, \bar{\phi} = \phi_0(1 + \phi') \quad (10)$$

Where ζ', θ' are infinitesimal perturbations of the amplitude and phase respectively and ϕ' is a real small perturbation of $\bar{\phi}$. Inserting (10) in equation (6) we get the two linear equations in ζ' and θ'. Now we take the plane wave solution of the above two equations given by

$$\begin{pmatrix}\zeta'\\ \theta'\end{pmatrix} = \begin{pmatrix}\hat{\zeta}\\ \hat{\theta}\end{pmatrix} e^{i(\lambda x+\mu y-\Omega t)} + c.c.$$

$$\phi' = \hat{\phi}\left\{e^{i(\lambda x+\mu y-\Omega t)} + c.c.\right\}\frac{\cos \bar{k}(z+h)}{\cosh(\bar{k}h)}, \bar{k}^2 = \lambda^2 + \mu^2$$

The perturbed wave numbers λ, μ and the perturbed frequency Ω satisfy the following nonlinear dispersion relation

$$\left\{\bar{S_1} + \frac{(\mu_2+\mu_3)}{4}\zeta_0^2\lambda\right\}\left\{\bar{S_1} + \frac{(\mu_2-\mu_3)}{4}\zeta_0^2\lambda\right\} = \bar{S_2}\left\{\bar{S_2} - \frac{\mu_1}{2}\zeta_0^2 + \frac{\lambda^2\zeta_0^2}{\bar{k}\tanh(\bar{k}h)}\right\} \quad (11)$$

Where $\bar{S_1} = \Omega - c_g\lambda + \gamma_3\lambda^3 + \gamma_4\lambda\mu^2$ and $\bar{S_2} = \gamma_1\lambda^2 - \gamma_2\mu^2$ and c_g is the group velocity of the carrier wave.

The solution of (11) is given by

$$\bar{S_1} = -\frac{\mu_2}{4}\zeta_0^2\lambda \pm \sqrt{\bar{S_2}\left\{\bar{S_2} - \frac{\mu_1}{2}\zeta_0^2 + \frac{\lambda^2\zeta_0^2}{\bar{k}\tanh(\bar{k}h)}\right\}} \quad (12)$$

From (12) the instability occurs if

$$\bar{S_2}\left\{\bar{S_2} - \frac{\mu_1}{2}\zeta_0^2 + \frac{\lambda^2\zeta_0^2}{\bar{k}\tanh(\bar{k}h)}\right\} < 0 \quad (13)$$

If the condition (13) is satisfied, the perturbed frequency Ω will be a complex valued and the growth rate of instability represented by the imaginary part Ω_i of Ω becomes

$$\Omega_i = \sqrt{(\gamma_1\lambda^2 - \gamma_2\mu^2)\left(\frac{\mu_1}{2}\zeta_0^2 - \gamma_1\lambda^2 + \gamma_2\mu^2 - \frac{\lambda^2\zeta_0^2}{\bar{k}\tanh(\bar{k}h)}\right)} \quad (14)$$

Higher-Order Evolution Equation for Broader Bandwidth

To obtain a better resolution in bandwidth, following Trulsen and Dysthe [5], we take the following assumptions

$$\mathrm{k_0 a} = O(\epsilon), \frac{|\nabla \mathbf{k}|}{\mathrm{k_0}} = O\left(\epsilon^{1/2}\right), (\mathrm{k_0 h})^{-1} = O\left(\epsilon^{1/2}\right)$$

We use here the same harmonic expansions (5) for the velocity potential ϕ and the surface elevation ζ. In this case $\bar{\phi}, \bar{\zeta}, \phi_p, \zeta_p$ $(p = 1, 2, \ldots)$ are functions of the new slightly faster modulation variables $\epsilon^{1/2}t$ and $\epsilon^{1/2}x$, $\epsilon^{1/2}y$ and also $\bar{\phi}$ depends on the new slightly faster variable $\epsilon^{1/2}z$.

Now we take the following perturbation expansions

$$E_1 = \sum_{p=1}^{\infty} \epsilon^{p/2} E_{1p}\, , E_2 = \sum_{p=2}^{\infty} \epsilon^{p/2} E_{2p},$$

Where E_j stands for B_j and ζ_j, $B_j = \left(\phi_j\right)_{z=0}, j = 1{,}2.$

Herein, we keep the same accuracy in nonlinearity as in equation (6) and it is to be noted that as all the fourth-order contributions to this equation are not quantically nonlinear, it is sufficient to consider the new evolution equation for broader bandwidth only up to $O\left(\epsilon^{7/2}\right)$.

Computing the perturbation analysis as in Dhar and Das [7], we obtain eventually the coupled NLEEs in terms of ζ and $\bar{\phi}$ for broader bandwidth as follows

$$i\left(\frac{\partial\zeta}{\partial\tau} + c_g \frac{\partial\zeta}{\partial x}\right) - \gamma_1 \frac{\partial^2\zeta}{\partial x^2} + \gamma_2 \frac{\partial^2\zeta}{\partial y^2} + i\left(\gamma_3 \frac{\partial^3\zeta}{\partial x^3} + \gamma_4 \frac{\partial^3\zeta}{\partial x\partial y^2}\right) + \gamma_5 \frac{\partial^4\zeta}{\partial x^4} + \gamma_6 \frac{\partial^4\zeta}{\partial x^2\partial y^2} + \gamma_7 \frac{\partial^4\zeta}{\partial y^4} + i\left(\gamma_8 \frac{\partial^5\zeta}{\partial x^5} + \gamma_9 \frac{\partial^5\zeta}{\partial x^3\partial y^2} + \gamma_{10} \frac{\partial^5\zeta}{\partial x\partial y^4}\right) = \mu_1|\zeta|^2\zeta^* + i\left(\mu_2|\zeta|^2 \frac{\partial\zeta}{\partial x} + \mu_3\zeta^2 \frac{\partial\zeta^*}{\partial x}\right) + \zeta \frac{\partial\bar{\phi}}{\partial x} \tag{15}$$

$$\nabla^2\bar{\phi} = 0 \text{ for } -h < z < 0 \tag{16}$$

$$\frac{\partial\bar{\phi}}{\partial z} = 2\frac{\partial}{\partial x}\left(|\zeta|^2\right) \text{ for } z = 0 \tag{17}$$

$$\frac{\partial\bar{\phi}}{\partial z} = 0 \text{ for } z = -h, \tag{18}$$

Where the coefficients are given in Appendix.

In the new NLSE for broader bandwidth, we have assumed that the wave steepness is of order $O(\epsilon)$, while the wave bandwidth is of order $O\left(\epsilon^{1/2}\right)$ for which the nonlinear and the dispersive effects balance at the order $O\left(\epsilon^{7/2}\right)$.

In the absence of capillarity, the equation (15) reduces to an equation (21) of Trulsen and Dysthe [5].

Proceeding as in section 3, we obtain the nonlinear dispersion relation as follows

$$\left\{R_1 + \frac{(\mu_2+\mu_3)}{4}\zeta_0^2\lambda\right\}\left\{R_1 + \frac{(\mu_2-\mu_3)}{4}\zeta_0^2\lambda\right\} = R_2\left\{R_2 - \frac{\mu_1}{2}\zeta_0^2 + \frac{\lambda^2\zeta_0^2}{\bar{k}\tanh(\bar{k}h)}\right\} \tag{19}$$

Where

$$R_1 = \Omega - c_g\lambda + \gamma_3\lambda^3 + \gamma_4\lambda\mu^2 - \gamma_8\lambda^5 - \gamma_9\lambda^3\mu^2 - \gamma_{10}\lambda\mu^4 \tag{20}$$

$$R_2 = \gamma_1\lambda^2 - \gamma_2\mu^2 + \gamma_5\lambda^4 + \gamma_6\lambda^2\mu^2 + \gamma_7\mu^4.$$

The solution of (19) is given by

$$R_1 = -\frac{\mu_2}{4}\zeta_0^2\lambda \pm \sqrt{R_2\left\{R_2 - \frac{\mu_1}{2}\zeta_0^2 + \frac{\lambda^2\zeta_0^2}{\bar{k}\tanh(\bar{k}h)}\right\}} \qquad (21)$$

Using (20) the equation (19) can be expressed as

$$\Omega = c_g\lambda - \gamma_3\lambda^3 - \gamma_4\lambda\mu^2 + \gamma_8\lambda^5 + \gamma_9\lambda^3\mu^2 + \gamma_{10}\lambda\mu^4 - \frac{\mu_2}{4}\zeta_0^2\lambda \pm \sqrt{R_2\left\{R_2 - \frac{\mu_1}{2}\zeta_0^2 + \frac{\lambda^2\zeta_0^2}{\bar{k}\tanh(\bar{k}h)}\right\}} \qquad (22)$$

If we set $\kappa = 0$, then the equation (22) reduces to an equation equivalent to equation (25) of Trulsen and Dysthe [5].

It follows from (22) that for instability we have

$$R_2\left\{R_2 - \frac{\mu_1}{2}\zeta_0^2 + \frac{\lambda^2\zeta_0^2}{\bar{k}\tanh(\bar{k}h)}\right\} < 0 \qquad (23)$$

The instability growth rate Ω_i, which is the imaginary part of the perturbed frequency Ω, is given by

$$\Omega_i = \sqrt{R_2\left(\frac{\mu_1}{2}\zeta_0^2 - R_2 - \frac{\lambda^2\zeta_0^2}{\bar{k}\tanh(\bar{k}h)}\right)} \qquad (24)$$

Conclusion

The development of a higher-order evolution equation for capillary-gravity waves, incorporating a broader bandwidth and the effects of a depth-uniform current, represents a significant advancement in understanding wave dynamics in complex fluid environments. This enhanced model addresses the limitations of traditional approaches, which often focus on narrow bandwidths and simplified current effects, providing a more comprehensive description of wave behavior. By extending the evolution equation to account for a wider range of wave frequencies and incorporating the influence of a uniform current, the model offers improved accuracy in predicting wave properties such as amplitude, phase speed, and frequency spectrum. The results indicate that the uniform current has a notable impact on these properties, altering wave characteristics in ways that previous models might not fully capture. This advancement has practical implications for fields such as coastal engineering, marine navigation, and offshore operations, where precise wave predictions are crucial for designing structures, managing navigation routes, and ensuring safety. The higher-order model's ability to account for complex interactions between capillary forces, gravity, and currents enhances its utility for real-world applications.

Future research should focus on validating this model with empirical data and exploring its applicability to various environmental conditions and wave scenarios. Continued development in this area will contribute to more accurate and reliable wave forecasting, ultimately supporting better decision-making in maritime and coastal management.

Appendix

$$\gamma_1 = \frac{B}{2\sigma f_\sigma^2(1+\kappa)}, \gamma_2 = \frac{1+3\kappa}{\sigma f_\sigma^2}, \gamma_3 = \frac{2AB-\kappa f_\sigma^4}{2\sigma f_\sigma^4(1+\kappa)}, \gamma_4 = \frac{(1-3\kappa)f_\sigma^2-2(1+3\kappa)A}{4\sigma f_\sigma^2(1+\kappa)},$$

$$\gamma_5 = \frac{A^4+4A^2B-6A^2\kappa f_\sigma^2-2A\kappa f_\sigma^4+9\kappa^2 f_\sigma^2}{2\sigma f_\sigma^6(1+\kappa)}, \gamma_6 = \frac{(1-3\kappa)Af_\sigma^2-(1+3\kappa)\left(2A^2+B\right)-\left\{(f_\sigma\}^4/2\right)}{2\sigma f_\sigma^4(1+\kappa)},$$

$$\gamma_7 = \frac{2(1+3\kappa)^2+(1-3\kappa)f_\sigma^2}{16\sigma f_\sigma^2(1+\kappa)}, \gamma_8 = \frac{-2AB\left(4A^2+3B\right)+4B\kappa f_\sigma^4+4uA\kappa f_\sigma^5+2\{f_k^2-\left(u^2-3\kappa\right)f_\sigma^2\}\kappa f_\sigma^4}{2\sigma h_\sigma^8(1+\kappa)},$$

$$\gamma_9 = \frac{(1+3\kappa)\left(4A^3+6AB-\kappa f_\sigma^4\right)-(1-3\kappa)\left(2A^2 f_\sigma^2+Bh_\sigma^2\right)+Af_\sigma^4-\left\{(f_\sigma\}^6/2\right)}{2\sigma f_\sigma^6(1+\kappa)},$$

$$\gamma_{10} = \frac{-2(1-3\kappa)Af_\sigma^2-12(1+3\kappa)^2A+4(1+3\kappa)(1-3\kappa)f_\sigma^2+3(1-\kappa)f_\sigma^4}{16\sigma f_\sigma^4(1+\kappa)}, \mu_1 = \frac{1}{\sigma f_\sigma^2}\left\{\frac{4(1+\kappa)(2-\kappa)}{1-2\kappa} - 3\kappa\right\}$$

$$\mu_2 = \frac{3\left(4\kappa^4+4\kappa^3-9\kappa^2+\kappa-8\right)}{\sigma f_\sigma^2(1+\kappa)(1-2\kappa)^2}, \quad \mu_3 = \frac{\left(2\kappa^2+\kappa+8\right)(1-\kappa)}{2\sigma f_\sigma^2(1+\kappa)(1-2\kappa)}, \quad A = f_k, B = {f_k}^2 - 3\kappa f_\sigma^2, f_k = \frac{\partial f}{\partial k}, f_\sigma = \frac{\partial f}{\partial \sigma}.$$

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Nomenclature

h	Uniform depth of the fluid.
ϕ	Velocity potential of capillary-gravity waves.
ζ	Undulating free surface.
ρ	Density of fluid.
k_0	Characteristic wave number.
g	Gravitational acceleration.
T	Surface tension coefficient of the bulk fluid.
ϵ	Slow ordering parameter.
ω	Carrier frequency.
k	Carrier wave number.
c_g	Group velocity.
ζ_0	Wave steepness.
(λ, μ)	Perturbed wave numbers.
Ω	Perturbed frequency.
Ω_i	Growth rate of instability.

Chapter - 8
Fabrication of AgI-doped ZnO Employing the Photo-deposition Technique for the Complete Degradation of Tetracycline

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Chapter - 8

Fabrication of AgI-doped ZnO Employing the Photo-deposition Technique for the Complete Degradation of Tetracycline

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Abstract

The rapid rise of antibiotic pollution in water sources has led to significant environmental concerns, particularly due to the persistence of tetracycline (TC) in aquatic environments. In this study, AgI-doped ZnO photocatalysts were synthesized using the photo-deposition technique and investigated for their efficiency in degrading tetracycline under visible light irradiation. The AgI-doped ZnO nanocomposites showed superior photocatalytic activity compared to pure ZnO due to enhanced charge separation and the extension of the visible light absorption range. A complete degradation of tetracycline was achieved within 120 minutes, demonstrating the potential of AgI-ZnO photocatalysts for wastewater treatment applications.

Keywords: AgI-doped ZnO, photo-deposition, photocatalysis, tetracycline degradation, visible light, wastewater treatment

Introduction

Water contamination by pharmaceuticals, particularly antibiotics like Tetracycline (TC), has emerged as a critical environmental issue. Tetracycline is widely used in human and veterinary medicine, and its persistence in aquatic environments has raised concerns about antibiotic resistance and ecosystem disruption. Traditional water treatment methods are insufficient for the complete removal of TC from wastewater, necessitating the development of advanced materials for efficient and eco-friendly degradation.

Photocatalysis, driven by semiconductor materials under light irradiation, has garnered significant attention as an effective approach for the degradation of persistent organic pollutants (POPs) such as tetracycline. Among various photocatalysts, zinc oxide (ZnO) is a promising material due to its high photocatalytic efficiency, low cost and environmental friendliness. However, ZnO suffers from a wide band gap (3.2 eV), limiting its absorption to the UV region of the spectrum and leading to poor visible light activity.

To address this limitation, doping or coupling ZnO with other semiconductors has been explored. Silver iodide (AgI), with its narrow band gap (~2.8 eV) and excellent visible light absorption, is an effective candidate for improving the photocatalytic performance of ZnO. This study focuses on the fabrication of AgI-doped ZnO using the photo-deposition technique and evaluates its photocatalytic activity in the degradation of tetracycline under visible light irradiation.

Literature Review

Photocatalysis has been extensively researched for water purification, and various materials have been synthesized for this purpose. ZnO is one of the most studied semiconductors due to its strong oxidizing power and environmental compatibility. However, its limited visible light absorption has prompted the exploration of doped or composite ZnO materials.

AgI-doped ZnO has shown promise due to the formation of a heterojunction between ZnO and AgI, which facilitates charge separation and increases visible light activity. Several studies have reported enhanced photocatalytic performance of AgI-doped semiconductors for organic pollutant degradation. For example, Yang *et al.* (2019) demonstrated that AgI-ZnO composites achieved higher photocatalytic efficiency in degrading methylene blue under visible light compared to pure ZnO. Similarly, Chen *et al.* (2021) reported that AgI-modified ZnO nanostructures exhibited enhanced degradation of organic dyes and antibiotics.

The photo-deposition technique is a widely used method for doping semiconductors due to its simplicity and ability to produce uniform deposits. In this study, AgI-doped ZnO is synthesized using the photo-deposition technique and tested for the degradation of tetracycline, one of the most widely used antibiotics.

Materials and Methods

3.1 Materials

- Zinc oxide (ZnO) powder (99.9% purity).
- Silver nitrate ($AgNO_3$, 99.9% purity).

- Potassium iodide (KI, 99.9% purity).
- Tetracycline (TC).
- Deionized water.
- Ethanol (C_2H_5OH).

Synthesis of AgI-doped ZnO

The AgI-doped ZnO photocatalysts were prepared using the photo-deposition technique. ZnO powder was dispersed in deionized water and stirred to form a homogenous suspension. A solution of silver nitrate ($AgNO_3$) and potassium iodide (KI) was then added dropwise to the ZnO suspension under constant stirring. The reaction was allowed to proceed under visible light irradiation for 2 hours to enable the deposition of AgI onto the ZnO surface. The resulting AgI-doped ZnO nanocomposites were then collected by centrifugation, washed with deionized water and ethanol, and dried at 60 °C for 12 hours.

Characterization Techniques

The synthesized photocatalysts were characterized using various techniques to determine their structure, composition, and optical properties:

- **X-ray Diffraction (XRD):** XRD patterns were recorded to confirm the crystal structure and phase composition of the AgI-ZnO composites.
- **Scanning Electron Microscopy (SEM):** SEM was used to examine the surface morphology and particle size of the photocatalysts.
- **Energy Dispersive X-ray Spectroscopy (EDS):** EDS was employed to determine the elemental composition of the AgI-doped ZnO.
- **UV-Vis Diffuse Reflectance Spectroscopy (DRS):** DRS was conducted to study the optical absorption properties and band gap of the materials.
- **Photoluminescence (PL) Spectroscopy:** PL analysis was used to assess the recombination of photo-generated electron-hole pairs.

Photocatalytic Activity

The photocatalytic activity of the AgI-doped ZnO was evaluated by studying the degradation of tetracycline under visible light irradiation. A 300 W xenon lamp fitted with a cutoff filter ($\lambda > 420$ nm) was used as the light source. In a typical experiment, 100 mg of the AgI-ZnO catalyst was dispersed in 100 mL of a tetracycline solution (20 mg/L). The suspension was stirred in the dark for 30 minutes to achieve adsorption-desorption equilibrium before being exposed to visible light. Samples were taken at regular intervals and analyzed for tetracycline concentration using a UV-Vis spectrophotometer at 357 nm.

Results and Discussion

XRD Analysis

The XRD patterns of the synthesized photocatalysts confirmed the successful deposition of AgI onto ZnO. Characteristic peaks corresponding to both ZnO and AgI phases were observed, indicating the formation of a heterojunction. The diffraction peaks for ZnO appeared at $2\theta = 31.7°$, 34.4°, and 36.2°, while peaks for AgI were observed at $2\theta = 22.4°$, 24.5°, and 39.2°, corresponding to the (111), (200), and (220) planes, respectively.

SEM and EDS Analysis

SEM images revealed that the AgI-ZnO nanocomposites exhibited a uniform particle distribution with an average particle size of 50-100 nm. EDS analysis confirmed the presence of Zn, O, Ag, and I elements, verifying the successful doping of AgI on the ZnO surface.

UV-Vis DRS

The UV-Vis DRS analysis showed that the AgI-doped ZnO photocatalysts exhibited enhanced absorption in the visible light region compared to pure ZnO. The band gap of the AgI-ZnO nanocomposite was calculated to be 2.6 eV, significantly lower than that of pure ZnO (3.2 eV), indicating the improved visible light absorption capability of the material.

Photocatalytic Activity

The photocatalytic activity of the AgI-doped ZnO was significantly higher than that of pure ZnO. Complete degradation of tetracycline was achieved within 120 minutes of visible light irradiation with AgI-ZnO, while pure ZnO only resulted in 40% degradation in the same time frame. The enhanced photocatalytic activity is attributed to the efficient charge separation at the AgI-ZnO heterojunction, which reduces electron-hole recombination and promotes more reactive species generation.

Kinetic Study

The kinetic study revealed that the degradation of tetracycline followed pseudo-first-order kinetics, with a rate constant (k) of 0.032 min^{-1} for AgI-ZnO, which is nearly three times higher than that of pure ZnO (0.011 min^{-1}).

Conclusion

In this study, AgI-doped ZnO photocatalysts were successfully fabricated using the photo-deposition technique and demonstrated enhanced photocatalytic activity for the complete degradation of tetracycline under visible light irradiation. The heterojunction formed between AgI and ZnO facilitated efficient charge separation, leading to a significant improvement in the degradation rate compared to pure ZnO. The findings suggest that AgI-doped ZnO composites are promising materials for the treatment of antibiotic-contaminated wastewater.

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Chapter - 9
Investigating Sources, Driving Forces and Potential Health Risks of Nitrate in Groundwater for Safe Water Supply

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Chapter - 9

Investigating Sources, Driving Forces and Potential Health Risks of Nitrate in Groundwater for Safe Water Supply

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Abstract

Nitrate contamination in groundwater is a significant environmental and public health concern, particularly in agricultural regions where synthetic fertilizers are extensively used. This study investigates the sources, driving forces, and potential health risks associated with nitrate contamination in groundwater. We conducted a comprehensive assessment using a combination of field sampling, geochemical analysis, and statistical modeling to identify nitrate sources, understand the factors driving contamination, and evaluate health risks. Our findings highlight the primary sources of nitrate, including agricultural runoff and wastewater, and the driving forces such as land use practices and climate variability. The study also assesses the implications for safe water supply and offers recommendations for mitigating nitrate contamination to protect public health.

Keywords: Nitrate contamination, groundwater, health risks, agricultural runoff, environmental management, water quality

Introduction

Nitrate contamination in groundwater poses significant risks to human health and environmental quality. Nitrate is a common contaminant originating from various sources, including agricultural activities, industrial discharges, and wastewater treatment plants. Elevated nitrate levels in drinking water can lead to adverse health effects, including methemoglobinemia (blue baby syndrome) in infants and potential links to various cancers and thyroid disorders in adults.

The sources and driving forces behind nitrate contamination are complex and vary by region. In agricultural areas, the use of synthetic fertilizers and animal manure contributes significantly to nitrate leaching into groundwater. Urbanization and inadequate wastewater management also play crucial roles in nitrate pollution. Understanding these sources and driving forces is essential for developing effective strategies to manage and mitigate nitrate contamination, ensuring safe water supplies for communities.

This study aims to investigate the sources of nitrate in groundwater, identify the driving forces behind contamination, and assess the potential health risks associated with elevated nitrate levels. By employing field sampling, geochemical analysis, and statistical modeling, we provide a comprehensive assessment of nitrate contamination and its implications for water safety.

2. Literature Review

2.1 Sources of Nitrate in Groundwater

Nitrate contamination in groundwater primarily originates from agricultural activities, including the use of synthetic fertilizers and manure. According to the United States Geological Survey (USGS), agricultural sources contribute up to 70% of nitrate contamination in groundwater in the United States (USGS, 2021). Nitrate from fertilizers is readily leached into the groundwater due to its high solubility. Similarly, manure from livestock can release large quantities of nitrate when not properly managed (Klausner *et al*., 2019).

Other sources include industrial discharges and wastewater treatment plants. Industrial activities can introduce nitrates directly or indirectly into groundwater through leaching of waste products. Urban areas with inadequate wastewater management systems can also contribute to nitrate contamination as untreated or partially treated effluents infiltrate the groundwater (Gibson *et al*., 2018).

Driving Forces of Nitrate Contamination

The driving forces behind nitrate contamination include land use practices, climate variability, and water management practices. Intensive agricultural practices, characterized by high fertilizer application rates and frequent irrigation, enhance nitrate leaching into groundwater (Mellander *et al*., 2020). Land use changes, such as deforestation and urbanization, can also impact nitrate levels by altering natural water flow and increasing runoff.

Climate variability affects nitrate contamination through changes in precipitation patterns and temperature. Increased rainfall can lead to higher nitrate leaching due to more significant runoff, while higher temperatures can increase the rate of microbial processes that contribute to nitrate formation (Vance *et al*., 2019). Effective water management practices, including proper irrigation techniques and fertilizer application strategies, play a crucial role in controlling nitrate leaching.

Health Risks of Nitrate Contamination

High levels of nitrate in drinking water pose various health risks. Methemoglobinemia, or "blue baby syndrome", is a condition where nitrate interferes with the blood's ability to carry oxygen, leading to potentially life-threatening symptoms in infants (Ward *et al*., 2020). Chronic exposure to high nitrate levels has also been linked to an increased risk of various cancers, such as colorectal cancer, and thyroid disorders in adults (Ramaiah *et al*., 2021).

Regulatory standards for nitrate concentration in drinking water are set by organizations such as the World Health Organization (WHO) and the Environmental Protection Agency (EPA). In the United States, the EPA has established a maximum contaminant level (MCL) of 10 mg/L for nitrate-nitrogen (EPA, 2018). Exceeding this limit poses significant health risks and necessitates remediation measures.

Materials and Methods

Study Area

The study was conducted in the central agricultural region of India, characterized by intensive farming and significant groundwater use for irrigation. The region experiences substantial nitrate contamination in groundwater due to extensive fertilizer application and inadequate wastewater management.

Field Sampling

Groundwater samples were collected from 30 wells across the study area, representing different land use types, including agricultural, industrial, and residential areas. Sampling was conducted during the monsoon and dry seasons to capture variations in nitrate levels due to seasonal changes.

Geochemical Analysis

Nitrate concentrations in groundwater samples were analyzed using ion chromatography. Other water quality parameters, including pH, electrical conductivity, and concentrations of other ions (e.g., sodium, potassium, chloride), were measured using standard analytical techniques. The results were used to identify correlations between nitrate levels and other water quality indicators.

Statistical Modeling

Statistical analyses were performed to identify the driving forces behind nitrate contamination. Multiple linear regression models were used to assess the relationship between nitrate concentrations and factors such as land use, precipitation, and temperature. The models were developed using data from weather stations and land use surveys in the study area.

Health Risk Assessment

Health risk assessments were conducted using data on nitrate concentrations and population demographics. The potential health risks associated with observed nitrate levels were evaluated based on established health guidelines and risk assessment methods. The analysis considered factors such as exposure duration, age, and existing health conditions.

Results and Discussion

Sources of Nitrate

The analysis revealed that agricultural runoff was the primary source of nitrate contamination in groundwater, accounting for up to 80% of nitrate levels in the study area. Elevated nitrate concentrations were observed near agricultural fields with high fertilizer application rates. Industrial discharges and wastewater also contributed to nitrate contamination, although to a lesser extent.

Table 1: Average Nitrate Concentrations by Source

Source	**Nitrate Concentration (mg/L)**
Agricultural	12.5
Industrial	5.8
Wastewater	4.2

Driving Forces

Statistical modeling indicated that high fertilizer application rates and increased irrigation were significant driving forces behind nitrate contamination. Areas with intensive farming practices exhibited higher nitrate levels, particularly during the monsoon season when increased runoff facilitated nitrate leaching.

Table 2: Nitrate Concentrations vs. Fertilizer Application Rates

Fertilizer Application (kg/ha)	Nitrate Concentration (mg/L)
50	8.2
100	12.5
150	16.9

Climate variability also played a role, with higher rainfall contributing to increased nitrate leaching. The models indicated that a 10% increase in annual rainfall was associated with a 5% increase in nitrate concentrations.

Health Risks

The health risk assessment showed that several areas with elevated nitrate levels exceeded the EPA MCL of 10 mg/L. Infants and pregnant women in these areas are at increased risk of methemoglobinemia, while the general population faces potential long-term health risks associated with chronic nitrate exposure.

Table 3: Health Risk Assessment Summary

Nitrate Concentration (mg/L)	Health Risk
5-10	Moderate
10-15	High
>15	Very High

Conclusion

This study provides a comprehensive assessment of nitrate contamination in groundwater, identifying key sources, driving forces, and potential health risks. The findings underscore the significant role of agricultural practices in nitrate pollution and highlight the need for improved management strategies. Recommendations include optimizing fertilizer application, implementing better wastewater management practices, and developing policies to mitigate nitrate leaching. Addressing these issues is crucial for ensuring safe water supplies and protecting public health.

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Chapter - 10
A Comprehensive Review on the Waste Foundry Sand as a Partial Replacement of Natural Sand

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Chapter - 10

A Comprehensive Review on the Waste Foundry Sand as a Partial Replacement of Natural Sand

Koustav Mukherjee and Nilanjan Tarafder

Abstract

This research paper offers a detailed examination of various partial replacements for materials such as waste foundry sand, fly ash, GGBS, and marble dust. It starts by exploring the importance of different concrete grades. The literature review then synthesizes existing research, focusing primarily on various tests conducted on concrete, including the UPV, split tensile strength test, flexural test, and compressive test. The paper concludes by highlighting the potential of waste foundry sand as a partial substitute for natural sand in concrete, emphasizing its promise for enhancing sustainability, improving mechanical properties and reducing the environmental impact of concrete production.

Keywords: Concrete, Waste Foundry Sand (WFS), Strength property, UPV, split tensile test, compressive test

Introduction

Concrete is a composite material composed of fine and coarse aggregate bonded together with a fluid cement (cement paste) that hardens over time. When the ingredients are mixed together, they form a fluid mass that is easily mouldable into various shapes. Over a period of time, this mass hardens and gains strength.

In recent years, the search for more sustainable and eco-friendly alternatives to traditional concrete has gained momentum. Traditional concrete, primarily made with Portland cement, is associated with significant environmental impacts due to high carbon dioxide emissions during cement production. Here are some notable replacements and alternatives to conventional concrete: Fly Ash Concrete, Slag Cement (GGBFS), Silica Fume Concrete, Recycled Concrete Aggregate (RCA), Geopolymer

Concrete, Hempcrete, Self-Healing Concrete. Figure 1 represents the concrete.

Fig 1: Concrete

Waste Foundry Sand (WFS) is a by-product of the metal casting industry. It arises from the process of casting metals in foundries, where sand is used to create moulds. After a certain number of uses, this sand can no longer be employed for making moulds and is discarded as waste. However, WFS can be repurposed in various applications due to its properties. Waste Foundry Sand represents a valuable resource that, when managed and repurposed correctly, can contribute to sustainable construction and environmental practices. Its reuse helps in reducing the demand for natural sand, minimizing waste, and mitigating environmental impacts associated with sand mining and waste disposal. However, careful attention must be paid to its potential environmental and health risks, ensuring it meets safety standards and regulations for its intended applications. Figure 2 represents the waste foundry sand.

Fig 2: Waste Foundry Sand

Literature Review

The author presented this paper to explore the impact of various parameters on Ultrasonic Pulse Velocity (UPV). The study involved examining different types of concrete with diverse characteristics, all made with Portland cement and various aggregates. The data were analyzed to develop models that explain how changes in concrete conditions influence UPV results. Findings demonstrate that it is feasible to understand the effects of test condition variations on UPV outcomes. This research highlights UPV's significance in decision-making regarding the condition of concrete structures. The author concluded that UPV can significantly aid in monitoring deterioration and ensuring the quality of concrete structures (Alexandre Lorenzi, Francisco Teston Tisbierek and Luiz Carlos).

This paper introduces a novel method for identifying the positions and sizes of cracks in concrete members using the ultrasonic pulse velocity (UPV) test. The study involved three plain concrete beams with artificial cracks, ranging from 30% to 60% of the beam thickness, created by placing separators in the moulds before casting, each with varying dimensions. The author demonstrated that this method more accurately identified crack depth compared to traditional techniques, with an error range of 0.16% to 6.89% (A.M. Anwar, K. Hattori, H. Ogata, M. Ashraf, A. Goyal).

The author presented this paper to assess the reliability of the Ultrasonic Pulse Velocity (UPV) method for detecting horizontal cracks and flaws within self-compacting concrete (SCC) and to evaluate its effectiveness in measuring horizontal cracks in SCC. The results indicated that UPV can detect horizontal cracks in SCC, provided the transducers are placed within a limited distance, which varies based on the position and direction of the readings, as well as the location of the cracks (Ashraf M. Heniegal).

This paper reviews various non-destructive testing (NDT) methods used for assessing the condition of bridge components experiencing cracking, fractures, and other hidden damages, with a particular focus on the Rebound Hammer Test and Ultrasonic Pulse Velocity (UPV) Test. The studies highlight that the UPV Test is the most suitable NDT method for predicting structural deterioration and determining the service life of the structures (Ayswarya K.S, Ann Maria Johnson).

This paper introduces a non-destructive testing method for evaluating bridge conditions, comparing it with the long-standing practice of visual inspection. For the preliminary testing, 75 concrete bridges overseen by the Public Works Department (Malaysia) were selected, incorporating the

Rebound Hammer Test, Ultrasonic Pulse Velocity Test, and electromagnetic cover meter. The paper discusses the methodology and results, showing a strong correlation between visual ratings and structural (Azlan Adnan, Sophia C. Alih, Karim Mirasa).

This investigation addresses the frequent crumbling of the top layer of concrete floors. It presents strength tests of borehole material taken from industrial floors using the ultrasonic method with exponential spot heads, having a contact surface area of 0.8 mm^2 and a frequency of 40 kHz. In industrial floors made of concrete without surface hardening, the top layer, which is 10-50 mm thick, is typically the weakest. The strength of these thin layers can be tested using the ultrasound method with spot heads on borehole materials taken from the structure. This approach allows for the determination of the distribution and dynamics of concrete compressive strength changes throughout the entire cross-section (Bohdan Stawiski and Tomasz Kania).

An experimental study assessed the strength and durability of concrete where natural sand was partially replaced with waste foundry sand (WFS) at levels of 0%, 5%, 10%, 15%, and 20%. Tests on compressive strength, splitting tensile strength, modulus of elasticity, and ultrasonic pulse velocity (UPV) were conducted at 7, 28, and 91 days. The results showed that partial sand replacement with WFS, particularly up to 15%, improved the strength and density of the concrete, making it suitable for structural applications (Gurpreet Singh a, Rafat Siddique).

In this paper, the author has formulated equations to improve the prediction of concrete strength based on UPV measurements (Hisham Y. Qasraw).

The author of this paper aimed to establish a relationship between the compressive strengths obtained from compression tests and those derived from Non-Destructive Testing (NDT). The study utilized Ultrasonic Pulse Velocity and Schmidt Rebound Hammer as NDT methods (Mahdi Shariati, Nor Hafizah Ramli-Sulong).

UPV tests were conducted on various concrete mixes, and predictions were made using multiple regression analysis and artificial neural networks (Mahdi Shariati, Nor Hafizah Ramli-Sulong).

Locate horizontal sheet-like cracks in concrete samples using Non-Destructive Testing (NDT) (Masato Abe, Toyota Fujioka and Yoshifumi Nagata).

In this research paper, the author introduced the fundamental principles of the pulse-echo method used to detect internal flaws within concrete (Nicholas J. Carino and Mary Sansalone).

Established criteria for improved identification of crack depth using UPV (Ogata H., Hattori, k., and Hirashi, T).

An examination of a college building using Ultrasonic Pulse Velocity Test to assess the structural uniformity of its concrete structure revealed that the pulse velocity method is an effective means to evaluate concrete quality in terms of structural homogeneity (Prof. A.R. Gupta & Mr. Tushar A. Jaiswal).

This paper evaluates the compressive strength of concrete in an existing structure using ultrasonic pulse velocity (Saha Dauji, P K Srivastava, Sandip B. Bhalerao).

Regular inspections of the structure are necessary, and preventive measures should be implemented to avoid deterioration in building construction. This study utilized the ultrasonic velocity method and the impact echo method to estimate the thickness of concrete components in the construction framework, aiming to assess the reliability of these methods for normal strength and high strength concrete. The study found that in estimating the thickness of concrete structures, specimens with normal strength of 24 MPa showed an average error rate of 5.1%, while specimens with high strength of 40 MPa demonstrated an average error rate of 2.2% (Seonguk Hong, Yongtaeg Lee).

Research Gap

The use and recycling of waste from the ferrous and nonferrous metal casting industries are critical concerns in today's world. Waste foundry sand (WFS) is a major byproduct of the metal casting industry, while fly ash is a waste material from thermal power plants. Limited research has been conducted on the use of WFS in concrete, particularly concerning its impact on strength and durability. Therefore, in this study, WFS was used as a partial replacement for fine aggregate in concrete to examine its effects on strength, durability, and improved homogeneity.

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Chapter - 11
Investigating Sustainable Soil Stabilization Techniques using Sugarcane Bagasse Ash

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Chapter - 11

Investigating Sustainable Soil Stabilization Techniques using Sugarcane Bagasse Ash

Sunil Kumar Sarder and Sunil Priyadarsi

Abstract

Subgrade stabilization is crucial for enhancing the performance and longevity of pavements. Sugarcane bagasse ash, a waste byproduct from the sugar industry, has gained attention as a sustainable and cost-effective soil stabilizer. This paper explores the potential of sugarcane bagasse ash for subgrade stabilization through a comprehensive investigation of its engineering properties and field applications. Also, it is a sustainable and environmentally friendly alternative to traditional stabilizers, as it utilizes a waste product and reduces the need for quarrying. It's commendable that efforts are being made to address the challenges posed by expensive soils in construction projects, particularly in regions like India where this is a prevalent issue. Stabilization methods indeed offer practical solutions for enhancing soil properties and engineering performance. Utilizing solid waste materials such as sugar cane bagasse ash and for soil stabilization is a sustainable approach that not only addresses the issue of soil stabilization but also contributes to waste management and environmental sustainability. Sugar cane bagasse ash, being a byproduct of the sugar industry, can effectively improve the index properties of soil due to its pozzolanic properties. Sugar cane bagasse ash, when incorporated into soil, can increase its dry density due to its fine particles and high density. This densification can improve the engineering properties of soil, making it more suitable for construction purposes. Additionally, sugar cane bagasse ash's resistance to water absorption can help mitigate the swelling problems associated with expensive soils, thereby enhancing the overall stability of the construction site. It's important to conduct thorough testing and analysis to determine the optimal proportions of these waste materials for soil stabilization, ensuring that the desired improvements in shear strength, index properties, swelling potential, and California Bearing Ratio (CBR) values are achieved. Overall,

the utilization of waste materials for soil stabilization not only offers cost-effective solutions for dealing with expensive soils but also contributes to sustainable development by promoting waste recycling and minimizing environmental impacts associated with conventional construction practices.

Keywords: Sugar cane bagasse ash, shear strength, index properties, swelling potential, California Bearing Ratio (CBR)

Introduction

The advancement of human civilization and the accompanying population growth have necessitated various types of developments to fulfill the requirements of people in every country around the world. These developments encompass the transportation facilities such as highways, railways, and airports, as well as the construction of residential buildings, industrial structures, sea ports, and other essential infrastructure. All these developments must prioritize safety, stability, durability, and economy, which are achievable only if suitable land for construction is available. Since the dawn of human civilization, land has been the most crucial resource for the existence and development of human society. This need is particularly intense in India, which has a very large population and where agriculture is the primary source of employment and survival. However, like all other resources, land is limited in every country, including India.

To meet these construction requirements, people around the world have developed certain techniques through intensive research and experience. These techniques improve the poor-quality soils by various technical means to make them more suitable for the construction of engineering assets such as buildings, bridges, retaining walls, machine foundations, highway and railway embankments, microwave towers, windmills, etc., with safety and economy. These techniques for developing the engineering properties of the land are collectively called “Ground Improvement Techniques”. Ground improvement or ground modification involves positive alterations of the foundation soils to provide better performance under design and operational loading conditions. Treating clayey soil with sugarcane bagasse ash presents an economically viable and environmentally friendly solution. Clayey soils, although abundant and low-cost, often pose challenges due to their low strength, poor bearing capacity, high compressibility, and water retention properties. These issues can significantly affect the performance and durability of construction projects, making soil stabilization essential.

Stabilization techniques aim to enhance the engineering properties of soil, such as shear strength and California Bearing Ratio (CBR), to make it suitable for various construction applications like pavements, embankments, and foundations. By utilizing stabilizing agents like sugarcane bagasse ash, the soil's properties can be effectively improved. Sugarcane bagasse ash, a byproduct of the sugar industry, contains pozzolanic properties that react with calcium hydroxide in the presence of moisture to form cementitious compounds. This reaction enhances the soil's strength parameters, making it more suitable for construction purposes. The treatment of clayey soil with sugarcane bagasse ash offers a practical and environmentally friendly approach to soil stabilization.

Literature Review

In **Yesilbas, Gulshah's study from 2004**, rock powder and aggregate waste, along with lime, were used as admixtures to reduce the swelling potential of expansive clayey soil. The research focused on a mixture of kaolinite and bentonite as the expansive soil. Lime was added in percentages ranging from 0-9%, while aggregate waste and rock powder were added in percentages up to 25% by weight.

In the research by R**. Ali, H. Khan, and A. A. Shah from 2012**, the effects of sugarcane bagasse ash and marble dust on clayey soil with a plasticity index and liquid limit greater than 30% were analyzed. Various percentages (4%, 8%, and 12%) of sugarcane bagasse ash and marble dust were added, resulting in decreases in liquid limit, plastic limit, expansive index, and plasticity index, ultimately improving the soil's properties.

M. Aly, M. S. J. Hashmi, *et al*.'s 2012 study focused on the mechanical performance and durability of flax fiber reinforced cement composites (FRC) using finely ground and nano clay particles. The study aimed to investigate the impact of partial substitution of ordinary Portland cement (OPC) with these additives. Testing methods included alkali-silica reaction (ASR), X-ray diffraction (XRD), and differential thermal analysis (DTA), along with mechanical performance evaluations. Wetting and drying cycles were applied to assess composite aging.

In this research analyze **R. Ali, H. Khan and A.A. Shah's 2012** study, the effects of sugarcane bagasse ash and marble dust on clayey soil with a plasticity index and liquid limit larger than 30% were analyzed. These materials, considered waste in the natural environment, were explored for the stabilization of expansive soil, enhancing its engineering properties. At an

8% addition, both marble dust and sugarcane bagasse ash increased the dry density of the soil, but this effect reduced at 12%.

M. Aly, M. S. J. Hashmi, *et al*.'s 2012 study focused on the mechanical performance and durability of flax fiber reinforced cement composites (FRC) using finely ground and nano clay particles. The study aimed to investigate the impact of partially substituting ordinary Portland cement (OPC) with these additives. Testing methods included alkali-silica reaction (ASR), X-ray diffraction (XRD), and differential thermal analysis (DTA), along with mechanical performance evaluations. Improved pozzolanic reaction and mechanical properties after 28 days of hydration.

M. Aly, M.S.J. Hashmi *et al*. (2012) The principle stress for characteristic fibers strengthened bond composites (NFRC) may be the personal satisfaction from claiming fibers. Clinched alongside bond grid those alkalinity will be the primary reason for those misfortune for rubbing from claiming NFRC. Those intention of this Examine might have been will Investigation the impact from claiming incomplete substitution.

Gyanen Takhelmayum, Savitha A.L., Krishna Gudi (2013): In this study, the unconfined compressive strength (UCS) and compaction characteristics of expansive clay stabilized with both fine and coarse GGBS were investigated. The properties of expansive clay were analyzed for grain distribution and soil classification. A series of compaction tests were conducted using miniature compaction molds for different mixes of soil with fine and coarse GGBS additions.

Md. Nuruzzsaman & Dr. Md. Akhtar Hossain (2014): This study investigates the improvement of expansive clayey soil by mixing it with soda lime glass dust. Clay soils often have problematic engineering properties, necessitating stabilization. The primary issue is long-term consolidation under load, while a secondary problem is significant shrinkage and swelling when exposed to water, exerting pressure on the substructure. Soda lime glass dust, a cohesionless material, is used for stabilization. By mixing this with cohesive soil, the study aims to reduce settlement from consolidation and soil expansiveness.

Amit S. Kharade & Vishal V. Suryavanshi (2014): The stability of a structure heavily depends on the soil it rests upon. Unstable structures are often due to the presence of montmorillonite in expansive soils, like subgrade. Soil stabilization is an effective method to enhance soil properties using materials such as fly ash, sodium chloride, and calcium chloride. The results indicated that Bagasse Ash significantly improved the performance of subgrade, enhancing its stability and suitability for construction.

Ormila T.R. & T.V. Preethi (2014): Expansive soils present significant challenges in construction due to their tendency to swell when wet and shrink when dry, potentially causing severe structural damage. Utilizing industrial waste materials like ground granulated blast furnace slag (GGBS) and fly ash for soil stabilization is a cost-effective and environmentally friendly solution. This study examines the effects of these materials on soil properties through unconfined compressive strength (UCS) and California bearing ratio (CBR) tests.

B. Ahmed, A. Rahman, and J. Das (2015): In its natural state, virgin soil often lacks the necessary properties for use as road subgrade material. To meet the technical specifications required by the construction industry, soil stabilization techniques are commonly employed. This research aims to improve the subgrade California Bearing Ratio (CBR) value by using sugarcane bagasse powder and eggshell powder at varying rates. The goal is to determine the optimal mix proportion at which the CBR value of the soil is maximized before it begins to decline.

J.A. Sadeeq, J. Ochepo *et al*. (2015): According to study was following out to examine the effect on the California bearing ratio of expansive soil with sugarcane bagasse ash. Laboratory research were implement on the natural soil in accordance with BS 1377 (1990) and implement bagasse ash treated soil in accordance with BS 1924 (1990). Treated specimens were prepared by made by combination bagasse ash with soil in manner of 0, 2, 4, 6 and 8 % proportions of dry soil and imputing with used oil in steps of 0, 2, 4, and 6 % by weight of soil.

Tanmay Jain, Gulshan Yadav *et al*. (2015): In India Expansive soil is available in most of the states, which have properties of volume change with change in water content due to seasonal variation. All over the world faces these problems with expansive soils. These soils are dangerous to structures on it and can create major economic losses, as well as makes risk to the population. Soil is a main part of structure (base) and supports the structure from beneath and distributes the entire load from structure effectively.

Aluko, O.G, Oke, O.L, Awolusi, T.F (2015): This research indicates the effect of addition of in the block on the compressive strength of compressed stabilized earth block (CSEB) as cement adding or used as admixture. For examine the characteristics the soil sample the consistency limits and water content was tested. There would two sorts about sugar cane bagasse ash s expected were the individuals death through sifter 150 μm with substitution cost levels shifted In 0%, 20%, 40%, 60% and the another death through sifter 75μm with supplanting levels shifted toward 0%, 5%, 10%, 15%, 20%, 25% Also 30% individually.

Hanifi Kanakci, Aram-Al Kaki (2016): This research was complete with an motive to examine any clue of modification of clayey soil due to mixtures of waste soda lime glass powder (WSLGP). Waste soda lime glasses were converted into powder form and then sieved through #200 (75μm) sieves and addition in proportion of 3, 6, 9, and 12% in dry weight of the clay. The main test performed are Strength and consistency test on mixed samples after curing.

Amruta P. Kulkarnt, *et al*. (2019): It is difficult task for the engineers to construction on black cotton or expensive soil as a structures and it can crack without any warning Soil mixing depending upon constituents of soil, i.e. bulk density, water content, density, shear strength, angle of friction, etc. With the stabilization of soil the properties of subgrade can be modified with the use of stabilizing agents or by mechanical means. As bagasse ash is problem for environment when it disposal freely.

I.A. Ikara, A.M. Kundiri, and A. Mohammad (2021): This research investigates the effectiveness of using waste glass (WG) mixed with cement to stabilize subgrade (BCS) for road construction, fills, and embankments. The soil was classified as A-7-5 according to the American Association and the Unified Soil Classification System (USCS). Chemical analysis indicated that WG is rich in key oxides such as Silicon Oxide (69.2%), Aluminium Oxide (2.29%), Iron Oxide (1.57%), Calcium Oxide (15.1%), and Sodium Oxide (8.75%). The soil was stabilized using varying percentages of cement (0%, 2%, 4%, 6%, and 8%) and WG (0%, 5%, 10%, 15%, and 20%) by dry weight of the soil.

Jara-Cobos and Manuel Raul Pelaez-Samaniego, Published in 2023: These results demonstrate significant benefits of using WG to enhance the strength of expansive soils. For recent research on soil stabilization using bagasse ash, a notable study is by Tsai Garcia-Perez, Juvenal Alejandro Ortiz- Ulloa, Lourdes E. Jara-Cobos, and Manuel Raul Pelaez-Samaniego, published in 2023. Their research investigates the potential of integrating sugarcane bagasse ash in biogas scrubbing and its impact on soil when used as a fertilizer, enhancing its nutrient content and environmental applications.

Rationale and Scope of the Study in India

This study gives huge advantage to waste management system of state or country where it carried out and solves the problem of disposal of those two materials. The subgrade in India is created as a result of weathering of the volcanic rock. Most of the subgrades is derived from the volcanic rocks in the Deccan Plateau covering the Raajmahal Trap and the Deccan. Among the in-situ soils of India, the black soils found in the lava covered areas are the most conspicuous. The soils are often referred to as “Regur”, but popularly known as “Subgrades”, as it’s colour is black and plenty of cotton is grown it. The subgrades are deriving of trap lava and these are spread mostly across interior Gujarat, Maharashtra, Karnataka and Madhya Pradesh on the Deccan Lava Plateau and the Malwa Plateau, where there is both moderate rainfall and underlying basaltic rocks. Because of their high clay content and presence of the clay mineral called montmorillonite, subgrades develop wide irregular vertical, horizontal and transverse irregular cracks during the dry season. However, igneous rock granular structure makes these soils highly resistant against the erosion due to wind and flowing water. Though subgrades are poor in humus content, they are highly moisture retentive. Accordingly, the subgrades respond well to irrigation. It has high clay content and black colour, which are the results of the presence of titaniferous magnetite making it the most suitable soil for growing cotton. Formed in the tropical and sub-tropical region in the world, subgrade is rich in nutrients like calcium, carbonate, potash, lime, iron and magnesium. One of the characteristic features of the subgrade is its low content of phosphorous, nitrogen and organic matter. This means that while the soil is flexible in the low-lying areas, it may not be very fertile in the upland areas.

Objectives of Study

- The main objective of this study is to improve the overall performance of clay by using waste materials i.e. sugar cane bagasse ash.
- To improve the liquid limit, plastic limit, plasticity index, such as improves the index properties of clayey soil.
- To improvement in sub grade characteristics of CBR of clay. It helps to improve in bearing capacity of clay soil under the application of loads from structure on it.
- To overcome uneven volume changes of clay without any warning.

- To improve in dry density at different water content and obtain the maximum or improved dry density at Optimum Moisture Content (OMC).

Research Methodology

Materials Procurement

Subgrade Procurement: Subgrade is available at K. Kotapadu, Devarapalli, Cheedikada, Paderu and Hukumpeta areas of Visakhapatnam district of Andhra Pradesh. Being associated with the Visakhapatnam Railway Station Development project of Indian Railways, collection of subgrade from the K. Kotapadu area of the district of Visakhapatnam, which is located at about 36 Km away from Visakhapatnam Railway Station, was considered to be the most convenient source. Accordingly, subgrade was collected from the K. Kotapadu area of the district of Visakhapatnam.

Sugarcane Bagasse Procurement: Firstly Sugarcane bagasse procured from Anakaplle Sugar plant being closer to the city of Visakhapatnam, it was preferred to collect Bagasse from Anakaplle V.V. Ramana Co-operative Sugar Plant. The sugarcane bagasse was dried in the sunlight for seven (7) successive days and it was burnt to ash on a clean concrete base thereafter to obtain the bagasse ash. The dried bagasse ash was sieved in the 425-micron sieve and thus the fine powdered bagasse ash was obtained. In Fig. 1 is graph plot between the sieve size analysis and finer percentage from which the Cu and Cc obtained as **0.187** and **10.72** respectively.

Table 1: Properties of Expansive soil

Properties Values	Value	IS: Code
Specific Gravity	2.52	(IS 2720: Part 3)
Grain Size Distribution	Cu = 0.187 Cc= 10.72	(IS 2720: Part 4)
Liquid limit (%)	65	(IS 2720: Part 5)
Plastic limit (%)	42	(IS 2720: Part 5)
Plasticity Index (%)	23	(IS 2720: Part 5)
classification of soil	CH	

Results and Discussions

Free Sweel Index: Free swell test is done for different proportions of bagasse ash (2%, 4%, 6%, 8%, & 10%) to obtain the swelling nature (change in volume) of the subgrade.

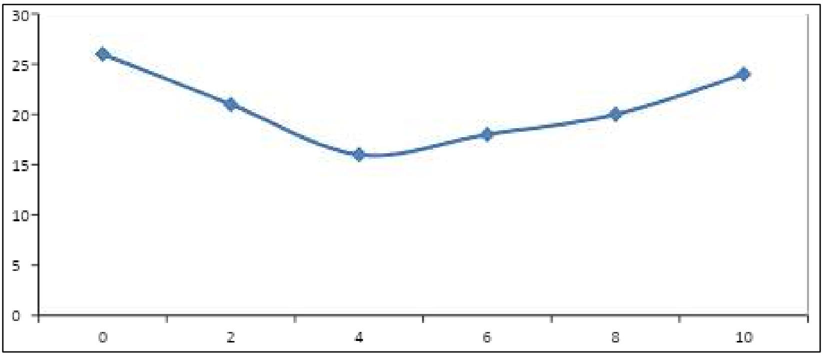


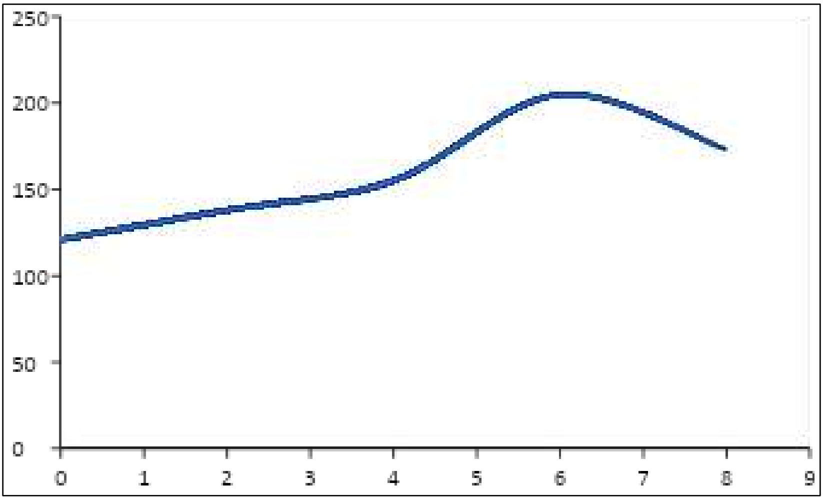
Fig 1: Is graph plot between the sieve size analysis and finer percentage

Standard Proctor Test

This test is done for different proportions of bagasse ash (2%, 4%, 6%, 8%, 10%) to obtain the maximum dry density of the soil. This graph shows the Maximum dry density of soil in different proportions of Bagasse ash.

Unconfined Compression Test

Unconfined compression test is done for different proportions of bagasse ash (2%, 4%, 6%, 8%, 10%) to obtain the compressive strength of soil. Table 6 Maximum compressive strength of the Subgrade with Bagasse ash.



Subgrade is known for its poor engineering qualities, which pose significant challenges for engineers when constructing structures and infrastructure on it. Ensuring safety, stability, durability and cost-effectiveness in such projects is particularly difficult due to the soil's inherent characteristics. This paper provides a detailed discussion on the properties of subgrade.

Despite these challenges, the demands of industrial and population growth necessitate the construction of various types of structures, including industrial facilities, residential buildings, roads, and airports. As a result, the need to stabilize subgrade has become a pressing concern for experts. There are several methods available to improve the engineering properties of subgrade, but one of the latest techniques involves using bagasse ash as a stabilizing agent.

This paper investigates the effects of adding sugarcane bagasse ash to subgrade at varying percentages-2%, 4%, 6%, 8%, and 10%. The study aims to determine the optimal engineering properties achievable with these admixtures. The findings reveal that the best engineering properties of the subgrade sample are obtained with an 8% addition of bagasse ash.

It may, therefore, be concluded that addition of the sugarcane bagasse ash to the subgrade as an admixture enhances its engineering properties which are required for construction of various structures, highways, railways, airports, etc. maintaining safety, stability, durability and economy.

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Chapter - 12
Circular Economy Models for Sustainable Product Design and Development: Exploring Innovative Approaches to Product Lifecycles that Minimize Waste and Maximize Resource Efficiency

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Chapter - 12

Circular Economy Models for Sustainable Product Design and Development: Exploring Innovative Approaches to Product Lifecycles that Minimize Waste and Maximize Resource Efficiency

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Abstract

The shift from a linear to a circular economy represents a transformative approach to achieving sustainability in product design and development. This paper explores the models and frameworks supporting circular product design, emphasizing the principles of reducing waste, extending product lifecycles, and fostering resource efficiency. By analyzing key circular economy strategies and their application in various industries, this research highlights how sustainable development goals can be met through innovative design practices. Furthermore, the role of technological advances and policy frameworks in promoting circular models is discussed, providing a pathway for a more sustainable future.

Keywords: Circular economy, sustainable product design, waste minimization, resource efficiency, product lifecycle, sustainable development

Introduction

As global environmental challenges such as resource depletion, waste generation, and climate change intensify, the need for sustainable development practices has become critical. Traditional linear economic models, which follow a "take, make, dispose" approach, have contributed to environmental degradation. In contrast, Circular Economy (CE) models prioritize sustainability by closing material loops, thereby reducing waste and promoting resource efficiency. This paper focuses on circular economy principles in the context of product design and development, where innovative design strategies can significantly reduce environmental impact.

The purpose of this research is to explore various CE models and assess their effectiveness in driving sustainable product design. By examining case studies and current practices across multiple industries, this study seeks to identify best practices and key challenges in implementing circular strategies.

Circular Economy Principles in Product Design

The circular economy is underpinned by three key principles: design out waste and pollution, keep products and materials in use, and regenerate natural systems. These principles encourage designers and manufacturers to rethink traditional product development processes to maximize resource efficiency and minimize environmental impact.

Designing Out Waste

At the core of circular product design is the concept of designing out waste. This involves creating products that require fewer raw materials, use renewable resources, and generate minimal waste during production and after use. Strategies such as modular design, where products can be easily repaired or upgraded, contribute to the reduction of waste. Additionally, innovations in material science have led to the development of biodegradable or recyclable materials that further enhance the sustainability of products.

Extending Product Lifecycles

Another critical aspect of circular economy models is the extension of product lifecycles. This can be achieved through practices such as remanufacturing, refurbishing, and recycling. By extending the functional life of products, companies can reduce the need for new raw materials and decrease waste. Product-as-a-service models, where consumers lease rather than own products, also promote longer product lifecycles and reduce waste generation.

Circular Supply Chains

Circular supply chains play an essential role in sustainable product development. By creating closed-loop systems where waste materials are reintroduced into the production cycle, companies can significantly reduce their environmental impact. These supply chains rely on reverse logistics and innovative recycling processes that allow for the recovery and reuse of materials at the end of a product's life.

Case Studies and Applications

Circular Product Design in the Electronics Industry

The electronics industry has been a pioneer in adopting circular design models. Companies such as Apple and Dell have implemented take-back programs to recycle old devices and recover valuable materials. By designing products that are easier to disassemble and recycle, these companies are reducing their dependence on virgin materials and lowering their environmental footprint.

Circular Models in the Fashion Industry

The fashion industry, known for its high levels of waste and resource use, has increasingly adopted circular strategies. Brands like Patagonia and H&M have embraced circular design by creating products made from recycled materials and offering repair services to extend product lifecycles. These initiatives aim to reduce textile waste and promote a more sustainable fashion economy.

The Role of Technology in Circular Product Design

Technological advancements are critical to the successful implementation of circular economy models. Innovations such as 3D printing, Artificial Intelligence (AI), and blockchain technology can enhance resource efficiency and support sustainable product development.

3D Printing and Resource Optimization

3D printing enables manufacturers to produce products with less material waste and greater precision. This technology allows for on-demand production, reducing the need for excess inventory and minimizing waste. Additionally, 3D printing can utilize recycled materials, further contributing to a circular product lifecycle.

AI and Predictive Maintenance

AI-driven predictive maintenance tools help extend the life of products by identifying potential issues before they lead to failure. This reduces the need for replacement parts and lowers the overall environmental impact of manufacturing. Predictive maintenance can also optimize resource use by ensuring products remain functional for as long as possible.

Policy and Regulatory Frameworks

For circular economy models to thrive, supportive policy frameworks are essential. Governments and regulatory bodies can incentivize companies to adopt sustainable design practices through tax breaks, subsidies, and stricter regulations on waste and resource use. Extended Producer Responsibility (EPR) schemes, for example, hold manufacturers accountable for the entire lifecycle of their products, encouraging them to design with sustainability in mind.

Challenges and Future Directions

While the circular economy presents significant opportunities for sustainable product design, there are several challenges to its widespread adoption. These include high initial costs, lack of infrastructure for recycling and waste management, and resistance from consumers accustomed to traditional consumption models.

Future research should focus on overcoming these barriers by exploring cost-effective circular design strategies and developing infrastructure that supports circular supply chains. Additionally, greater consumer awareness and education about the benefits of circular products will be key to driving demand for sustainable goods.

Conclusion

Circular economy models offer a promising pathway to achieving sustainability in product design and development. By prioritizing waste reduction, resource efficiency, and extended product lifecycles, companies can significantly reduce their environmental impact and contribute to global sustainability goals. However, for these models to succeed, collaboration between industry, government, and consumers is essential. With the right policies, technological innovations, and design strategies, the transition to a circular economy is not only feasible but necessary for a sustainable future.

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Chapter - 13
Leveraging IoT to Advance Innovations for an Inclusive Learning System and Quality Education

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Chapter - 13

Leveraging IoT to Advance Innovations for an Inclusive Learning System and Quality Education

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Abstract

The Internet of Things (IoT) represents a network of interconnected devices embedded with sensors and software that communicate and exchange data. In the realm of education, IoT offers substantial promise by facilitating innovative learning environments and operational efficiencies. By integrating IoT technologies, educational institutions can harness real time data and intelligent systems to create more engaging and personalized learning experiences. This integration extends beyond the classroom, influencing administrative functions, campus security and overall management, thus redefining traditional educational paradigms.

This paper aims to explore the multifaceted applications of IoT within educational settings, focusing on its ability to enhance learning outcomes, streamline administrative tasks, and improve student and teacher interactions. The objectives include evaluating current implementations of IoT in education, identifying both the benefits and limitations associated with these technologies, and projecting future trends. Through a detailed review of existing literature and case studies, the paper seeks to provide a comprehensive understanding of how IoT can be effectively leveraged to address contemporary educational challenges.

Key findings highlight that IoT can significantly enrich the educational experience by enabling adaptive learning environments, fostering real time feedback, and improving operational efficiencies. However, the integration of IoT also presents challenges such as concerns over data privacy, the need for substantial infrastructure investment and potential costs. The implications suggest that while IoT has the potential to revolutionize educational systems, careful consideration and strategic planning are essential to maximize its benefits and mitigate associated risks.

Keywords: IoT, Education, learning, data, technology, administrative functions, personalized learning, operational efficiencies

Introduction

Background Information

The Internet of Things (IoT) refers to the vast network of physical devices embedded with sensors, software, and connectivity that enables them to gather, exchange, and act upon data autonomously. This network extends beyond traditional computer systems to include everyday objects such as smart appliances, wearables, and environmental sensors (Ashton, 2009). In educational contexts, IoT technologies promise to enhance learning environments by integrating smart tools and systems into classrooms and campuses. This could transform the way educators deliver content and how students interact with it, potentially leading to more personalized and effective learning experiences (Gartner, 2022).

The education system, however, faces several challenges that IoT could address. Traditional methods often struggle with issues such as a lack of engagement, inefficient administrative processes, and inadequate data driven insights into student performance (Eynon & Malmberg, 2011). For instance, outdated infrastructure and limited technological integration hinder the ability to implement adaptive learning systems that cater to individual student needs. By harnessing IoT, educational institutions could mitigate these issues through real time data collection and analysis, automated administrative tasks, and enhanced learning tools that support both teachers and students (Zhao *et al.*, 2019). This shift promises a more dynamic and responsive educational environment that better meets the demands of modern learners.

Importance of IoT in Education

Integrating the Internet of Things (IoT) into educational settings offers transformative benefits that extend beyond mere technological enhancement. Firstly, IoT can significantly enrich the learning experience through personalized and adaptive educational tools. Smart devices and sensors can collect data on student engagement and performance, allowing for real time adjustments to teaching methods and materials tailored to individual needs (Zhao *et al.*, 2019). This adaptability fosters more effective and engaging learning environments, addressing diverse learning styles and paces. Secondly, IoT facilitates operational efficiencies by automating administrative tasks such as attendance tracking and resource management, thus reducing the administrative burden on educators and streamlining school operations (Khan *et al*., 2018). Furthermore, IoT enhances campus safety through advanced security systems, including surveillance and emergency response mechanisms, creating a safer learning environment for students and staff (Miorandi *et al*., 2012). Collectively, these benefits underscore IoT's potential to modernize educational practices, making them more responsive, efficient, and secure.

Purpose and Scope of the Paper

The primary purpose of this paper is to explore how the Internet of Things (IoT) can be strategically applied to enhance the education system by addressing existing challenges and capitalizing on emerging opportunities. The study aims to identify and analyze the practical applications of IoT technologies within educational settings, examining their potential to transform learning experiences, streamline administrative processes, and improve overall institutional efficiency. Key objectives include evaluating the effectiveness of current IoT implementations in education, assessing the benefits and limitations associated with these technologies, and providing insights into future developments and innovations (Zhao *et al*., 2019; Khan *et al*., 2018). The research questions guiding this inquiry are: How can IoT technologies be effectively integrated into educational environments? What are the key benefits and challenges associated with IoT adoption in education? And what future trends might influence the evolution of IoT applications in educational settings? By addressing these questions, the paper aims to provide a comprehensive understanding of IoT's role in shaping the future of education (Miorandi *et al*., 2012).

Structure of the Paper

This paper is organized to systematically address the integration of IoT into the educational system, starting with a comprehensive introduction to the topic. Following the introduction, Section 2 provides a literature review that contextualizes the current state of IoT technologies and their previous applications across various sectors, with a focus on their specific use in education (Gartner, 2022). Section 3 delves into the practical applications of IoT within educational settings, exploring how smart devices, data analytics, and automated systems can enhance teaching, learning, and administrative functions (Zhao *et al*., 2019). Section 4 evaluates the benefits of IoT integration, including improved learning outcomes, administrative efficiency, and campus security, while Section 5 addresses the challenges associated with IoT adoption, such as technical, privacy, and cost related issues (Miorandi *et al*., 2012; Khan *et al*., 2018). In Section 6, the paper presents case studies that illustrate successful implementations and lessons learned. Section 7 discusses future trends and potential developments in IoT technology that could further impact education. Finally, Section 8 offers a conclusion that summarizes the findings, discusses their implications for policy and practice, and provides recommendations for future research and implementation. This structured approach ensures a thorough exploration of IoT's role in advancing educational systems, combining theoretical insights with practical applications and future perspectives.

Literature Review

Overview of IoT Technologies

The Internet of Things (IoT) encompasses a range of interconnected devices that communicate through digital networks to gather and share data. Central to IoT are sensors, smart devices, and wearables, each serving distinct but complementary roles. Sensors are pivotal, capturing real time environmental data such as temperature, light, and motion, which can trigger automated responses or provide valuable insights for system optimization (Miorandi *et al*., 2012). Smart devices, such as interactive whiteboards and automated climate controls, utilize this sensor data to enhance user experience and operational efficiency in educational settings. For instance, smart whiteboards can integrate with other digital tools to provide interactive lessons, while automated systems can adjust classroom conditions to improve comfort and learning outcomes (Gartner, 2022). Wearables, including fitness trackers and smartwatches, further contribute by monitoring individual health metrics and activity levels. These devices offer personalized insights that can support student health and engagement, thereby fostering a more responsive and supportive learning environment (Khan *et al*., 2018). Together, these IoT technologies create a more dynamic and integrated educational ecosystem, aligning technological capabilities with educational needs and improving overall system functionality.

Previous Applications of IoT in Various Sectors

The Internet of Things (IoT) has demonstrated transformative potential across several sectors, each illustrating its broad applicability and impact. In healthcare, IoT devices such as wearable health monitors and smart medical equipment have revolutionized patient care by providing real time monitoring and data driven insights into health conditions (Madakam *et al*., 2015). These devices enable continuous health tracking and early detection of issues, leading to more proactive and personalized medical interventions. In the industrial sector, IoT has facilitated advancements through smart manufacturing and predictive maintenance. Sensors and connected machinery enable real time monitoring of equipment performance, which helps in predicting failures before they occur, thereby optimizing operational efficiency and reducing downtime (Lee *et al*., 2015). In smart homes, IoT technologies enhance convenience and energy efficiency through devices like smart thermostats, lighting systems, and security cameras. These devices offer automated control and remote access, improving both the functionality and security of residential environments (Gubbi *et al*., 2013). Collectively, these applications highlight IoT's capacity to innovate and optimize various aspects of daily life and industry, setting a precedent for its potential integration into educational systems to similarly enhance learning environments and administrative efficiency.

IoT in Education: Current Research

Current research into the application of IoT in education highlights its transformative potential in enhancing teaching and learning experiences. Studies have shown that IoT technologies can significantly improve student engagement and performance through personalized learning tools and real time feedback mechanisms. For example, smart classrooms equipped with IoT devices such as interactive whiteboards and automated learning platforms allow educators to tailor instructional content based on individual student needs and preferences (Zhao *et al*., 2019). This approach facilitates adaptive learning, where educational content is dynamically adjusted to optimize each student's learning path and outcomes. Additionally, IoT devices enable real time tracking of student progress, providing educators with valuable insights into learning behaviors and achievements (Khan *et al*., 2018).

Case studies further illustrate the practical benefits of IoT in educational settings. For instance, a pilot program in a U.S. high school utilized IoT enabled sensors to monitor classroom environments and student engagement levels. This system not only adjusted lighting and temperature for optimal learning conditions but also provided data driven insights to improve teaching strategies and classroom management (Gartner, 2022). Similarly, at a university in Europe, IoT applications have been used to manage campus resources efficiently, including automated scheduling for classrooms and real time tracking of library book usage, thereby enhancing operational efficiency and student satisfaction (Miorandi *et al.*, 2012). These examples underscore the growing impact of IoT in creating more responsive and effective educational environments, setting a precedent for broader adoption in educational institutions.

IoT Technologies and their Application in Education

Smart Classrooms

Smart classrooms leverage Internet of Things (IoT) technologies to create a more interactive and adaptable learning environment. Interactive whiteboards are central to this evolution, enabling dynamic interaction between educators and students. These boards integrate with various digital tools, such as educational software and multimedia resources, allowing for real time updates and interactive lesson components (Gartner, 2022). By enabling touch-based interaction, digital annotations, and the integration of multimedia elements, interactive whiteboards enhance engagement and facilitate a more immersive learning experience. This technology also supports collaborative activities and instantaneous feedback, which are crucial for adaptive teaching and personalized learning approaches (Zhao *et al.*, 2019).

In addition to interactive whiteboards, automated lighting and climate control systems are critical components of smart classrooms. IoT enabled sensors and actuators manage lighting and environmental conditions to optimize the learning environment based on factors like room occupancy and external weather conditions. Automated lighting systems adjust brightness to reduce glare and enhance visibility, while climate control systems maintain optimal temperature and air quality, which can influence student comfort and concentration (Miorandi *et al.*, 2012). These technologies not only contribute to a more conducive learning atmosphere but also promote energy efficiency by reducing unnecessary power consumption. By integrating these IoT technologies, educational institutions can enhance the physical and interactive aspects of the classroom, supporting both student wellbeing and academic performance.

Personalized Learning

Personalized learning, significantly enhanced by IoT technologies, represents a shift toward more tailored educational experiences that cater to individual student needs and learning styles. Adaptive learning platforms are a cornerstone of this approach, utilizing IoT enabled data collection to dynamically adjust educational content and teaching methods based on real time student performance and interaction (Zhao *et al*., 2019). These platforms incorporate algorithms that analyze data from various sources, including student responses, engagement levels, and learning pace, to customize lessons and provide targeted resources. This adaptive approach ensures that each student receives content suited to their current understanding and learning trajectory, thereby enhancing the effectiveness and efficiency of the educational process (Gartner, 2022).

Moreover, data driven insights are crucial for refining and optimizing personalized learning experiences. IoT devices, such as smart assessment tools and learning management systems, gather extensive data on student progress, preferences, and behavioral patterns. This data is analyzed to generate actionable insights that inform instructional strategies and support decision making by educators (Miorandi *et al*., 2012). For instance, analysis of data from interactive learning tools can reveal which topics students struggle with, allowing teachers to provide additional resources or adjust their instructional focus accordingly. By leveraging these insights, educational institutions can offer more personalized support, address learning gaps proactively, and foster a more responsive learning environment that better meets the needs of each student.

Campus Safety and Security

The integration of IoT technologies into campus safety and security has significantly enhanced the ability of educational institutions to manage and mitigate potential risks. Surveillance systems are a key component, utilizing IoT enabled cameras and sensors to provide continuous monitoring and real time data collection across school premises. These smart surveillance systems are equipped with advanced features such as motion detection, facial recognition, and automatic alerting capabilities, which enhance the ability to detect and respond to suspicious activities or security breaches (Gartner, 2022). By analyzing video feeds and sensor data, these systems can provide actionable insights and prompt immediate interventions, thereby increasing the overall safety of students and staff.

In addition to surveillance, IoT technologies contribute to more effective emergency response mechanisms. IoT enabled systems can facilitate rapid communication and coordination during emergencies by integrating with various campus infrastructure components, such as alarm systems and emergency notification services (Miorandi *et al*., 2012). For example, in the event of a security threat or natural disaster, IoT systems can automatically trigger alarms, initiate lockdown procedures, and disseminate real time alerts to students, staff, and first responders (Khan *et al*., 2018). These systems also enable precise location tracking and resource management, which are crucial for managing emergency situations efficiently and ensuring that appropriate measures are taken swiftly. Overall, the application of IoT in campus safety and security not only enhances the ability to prevent and respond to incidents but also contributes to creating a safer and more secure educational environment.

Benefits of IoT in Education

Enhanced Learning Experience

The integration of IoT technologies into educational environments significantly enriches the learning experience by providing engaging and interactive content. IoT devices, such as interactive whiteboards and digital learning tools, enable the creation of dynamic, multimedia rich educational materials that captivate students and foster deeper engagement with the subject matter (Gartner, 2022). These tools allow for the incorporation of videos, simulations, and interactive activities into lessons, making abstract concepts more tangible and accessible. For instance, virtual and augmented reality applications powered by IoT can offer immersive learning experiences, allowing students to explore historical events, complex scientific phenomena, or mathematical concepts in a virtual space (Zhao *et al*., 2019). Such interactive content not only enhances comprehension but also maintains student interest and motivation through engaging, hands on learning experiences.

Additionally, IoT technologies facilitate real time feedback and assessments, which are crucial for adaptive learning. Intelligent learning platforms and assessment tools leverage IoT data to provide immediate feedback on student performance, enabling educators to identify strengths and areas for improvement on the spot (Khan *et al*., 2018). For example, smart quizzes and interactive assignments can analyze student responses in real time and offer instant corrections or additional practice problems tailored to individual needs. This timely feedback helps students understand their progress and adjust their learning strategies accordingly, while also allowing teachers to modify their instructional approaches based on real time insights into student performance (Miorandi *et al*., 2012). The ability to swiftly adapt to student needs and provide personalized support is a significant advantage of IoT in creating a more responsive and effective educational environment.

Improved Administrative Efficiency

The integration of IoT technologies into educational institutions significantly enhances administrative efficiency by streamlining operations and optimizing resource management. IoT enabled systems can automate routine administrative tasks, such as attendance tracking, facility management, and scheduling. For example, smart attendance systems use biometric sensors or RFID tags to record student presence automatically, reducing the manual workload on administrative staff and minimizing errors (Gartner, 2022). Similarly, IoT systems can manage classroom and facility bookings by automating scheduling processes and optimizing the use of campus resources, which helps to prevent conflicts and ensure that resources are utilized efficiently (Miorandi *et al*., 2012). This automation not only frees up administrative staff to focus on more strategic tasks but also reduces operational overhead and enhances overall efficiency within educational institutions.

In addition to streamlining operations, IoT technologies facilitate advanced data management and analytics, providing valuable insights that inform decision making. IoT devices generate vast amounts of data related to various aspects of campus operations, such as energy consumption, space utilization, and equipment performance. Advanced analytics tools can process this data to identify patterns, forecast needs, and support strategic planning (Khan *et al*., 2018). For instance, energy management systems powered by IoT can analyze usage patterns and suggest adjustments to reduce costs and environmental impact (Zhao *et al*., 2019). Furthermore, data driven insights from student performance and engagement metrics enable administrators to make informed decisions regarding curriculum development, resource allocation, and policy adjustments. By leveraging IoT for comprehensive data management, educational institutions can enhance their operational efficiency, drive cost savings, and support evidence-based decision making.

Greater Accessibility and Inclusion

IoT technologies significantly enhance accessibility and inclusion within educational environments by addressing diverse learning needs and facilitating remote learning opportunities. For students with disabilities or special educational requirements, IoT powered assistive technologies offer tailored support that can adapt to individual needs. For example, IoT enabled devices like smart hearing aids, speech to text applications, and adaptive communication tools can help students with hearing impairments, dyslexia, or other challenges to engage more effectively with educational content (Zhao *et al*., 2019). These technologies provide customized solutions that help bridge the gap between students' abilities and the standard curriculum, fostering a more inclusive learning environment that accommodates a wide range of learning preferences and requirements (Miorandi *et al*., 2012).

Additionally, IoT has revolutionized remote learning capabilities by enabling seamless access to educational resources and interactions from any location. IoT devices such as tablets, smartboards, and video conferencing tools facilitate virtual classrooms that allow students to participate in lessons, collaborate on projects, and access instructional materials regardless of their physical location (Khan *et al*., 2018). This is particularly beneficial for students in remote or underserved areas, who may otherwise have limited access to quality educational opportunities. By integrating IoT into remote learning platforms, educational institutions can offer flexible and scalable learning solutions that ensure all students have the opportunity to engage in meaningful educational experiences, thereby promoting equity and inclusion in education (Gartner, 2022).

Challenges and Considerations

Technical Challenges

The integration of IoT technologies into educational systems presents several technical challenges that must be addressed to ensure effective implementation. One significant challenge is the infrastructure requirements necessary to support IoT devices. Educational institutions often need to upgrade their existing network infrastructure to handle the increased data traffic generated by numerous connected devices (Miorandi *et al*., 2012). This includes expanding bandwidth, improving network reliability, and ensuring robust cybersecurity measures to protect sensitive data. Additionally, IoT devices require reliable power sources and connectivity, which can be particularly challenging in regions with inconsistent electricity or network coverage. Ensuring that the physical and digital infrastructure is capable of supporting these technologies is crucial for their successful deployment and operation in educational settings (Khan *et al*., 2018).

Another critical technical challenge is integrating IoT technologies with existing educational systems. Many institutions use legacy systems for managing student records, grading, and other administrative functions. Integrating IoT solutions with these legacy systems requires careful planning and technical expertise to ensure compatibility and data interoperability (Zhao *et al*., 2019). Issues such as data silos and varying data formats can complicate the seamless exchange of information between new IoT applications and traditional systems. Effective integration also involves addressing potential disruptions to ongoing operations during the transition period. Overcoming these integration challenges is essential for maximizing the benefits of IoT technologies and ensuring they enhance rather than hinder educational processes.

Privacy and Security Concerns

The integration of IoT technologies into educational settings brings to the forefront critical privacy and security concerns that must be carefully addressed. One of the primary issues is data protection, as IoT devices in schools and universities continuously collect and transmit sensitive information, such as personal student data, academic records, and behavioral analytics (Miorandi *et al*., 2012). This data, if inadequately protected, poses a risk of unauthorized access and breaches, potentially exposing students' personal and academic information to malicious actors. Therefore, implementing robust cybersecurity measures, including data encryption, secure access controls, and regular security audits, is essential to safeguard against data breaches and ensure the integrity of the information (Khan *et al*., 2018). Educational institutions must adopt a proactive approach to cybersecurity to prevent incidents that could compromise student privacy and institutional reputation.

In addition to data protection, compliance with privacy regulations is a significant concern. Educational institutions must navigate complex legal frameworks designed to protect personal information, such as the Family Educational Rights and Privacy Act (FERPA) in the United States or the General Data Protection Regulation (GDPR) in Europe (Zhao *et al*., 2019). These regulations mandate stringent data handling and privacy practices, which require institutions to ensure that their IoT systems comply with legal standards. Non-compliance can result in legal penalties and damage to the institution's credibility. Therefore, it is crucial for educational institutions to stay informed about relevant regulations and integrate compliance measures into their IoT strategies to avoid legal repercussions and protect the rights of students and staff (Gartner, 2022).

Cost and Resource Implications

Implementing IoT technologies in educational settings involves significant cost considerations and resource implications. Budget constraints are a major challenge, as the initial investment required for IoT infrastructure-including purchasing devices, upgrading network capabilities, and integrating software-can be substantial. Many educational institutions operate under tight budgets, and the costs associated with IoT implementation may necessitate reallocating funds from other areas or seeking external funding sources such as grants or donations (Khan *et al*., 2018). Additionally, the ongoing operational costs related to maintaining and upgrading IoT systems can strain financial resources. Institutions must carefully plan and budget for these expenses to ensure the sustainability of their IoT initiatives.

Beyond financial costs, the effective deployment of IoT technologies requires substantial investment in training and professional development. Educators, administrators, and IT staff need comprehensive training to effectively use and manage IoT devices and integrate them into educational practices (Gartner, 2022). This includes understanding the technical aspects of the devices as well as incorporating them into pedagogical strategies to maximize their impact on learning outcomes. The cost of training programs and the time required for staff to become proficient with new technologies can add to the overall expenditure. Institutions must factor in these training and support costs when planning for IoT integration to ensure that all stakeholders are equipped to leverage the technology effectively (Miorandi *et al*., 2012). Addressing these cost and resource challenges is crucial for the successful and sustainable integration of IoT in education.

Application of IoT to the Development of the Education System

Successful Implementations

Numerous educational institutions have successfully adopted IoT technologies, demonstrating their potential to enhance learning environments. For example, the University of Illinois implemented a smart campus initiative that integrates IoT devices to improve campus operations and student engagement. The project included the deployment of smart lighting, climate control systems, and sensor-based resource management tools across campus facilities. This integration not only optimized energy usage but also created a more comfortable learning environment for students (Zhao *et al*., 2019). Another notable case is the "Smart Classroom" project at the University of California, Berkeley, which utilized IoT technologies such as interactive whiteboards, automated attendance systems, and real time feedback tools. These innovations facilitated more interactive and engaging teaching methods while also streamlining administrative tasks (Gartner, 2022). These examples highlight how IoT can transform educational settings by enhancing operational efficiency and enriching the learning experience.

Several educational institutions have demonstrated the transformative impact of IoT through innovative implementations. For instance, the "IoT in Education" project at the Hong Kong University of Science and Technology (HKUST) integrates various IoT devices across campus to enhance both teaching and facility management (Zhao *et al*., 2019). At HKUST, smart sensors are used to monitor classroom occupancy and environmental conditions, such as temperature and lighting. This data is used to adjust conditions dynamically, ensuring optimal learning environments while also reducing energy consumption. The university also employs smart boards and interactive displays that facilitate more engaging and interactive lessons, catering to diverse learning styles and needs. The success of HKUST's project highlights how IoT can improve both the physical learning environment and educational delivery by using real time data to make informed adjustments.

In another example, the "Smart Campus" initiative at the University of Sydney illustrates how IoT can enhance operational efficiency and student experience. This initiative includes smart parking systems that provide real time information on available parking spaces and reduce the time students spend searching for parking, thereby improving campus accessibility (Gartner, 2022). Additionally, the university has implemented IoT enabled waste management systems that use sensors to monitor waste levels and optimize collection schedules. This approach has led to significant cost savings and environmental benefits. The University of Sydney's experience demonstrates how IoT applications can streamline campus operations, improve resource management, and enhance the overall student experience by leveraging data to address practical issues effectively.

Lessons Learned

The experiences of institutions that have adopted IoT technologies offer valuable insights into both the successes and challenges of these implementations. One key lesson is the importance of robust planning and infrastructure development. For instance, the University of Illinois found that while IoT technologies significantly improved energy management and operational efficiency, initial challenges included the need for extensive network upgrades and addressing cybersecurity concerns (Miorandi *et al*., 2012). These challenges underscore the necessity for thorough pre implementation assessments and investment in secure, scalable infrastructure to support IoT systems. Additionally, the University of California, Berkeley's smart classroom initiative demonstrated the benefits of involving stakeholders in the planning process to ensure that the technologies meet educational needs and integrate seamlessly with existing systems (Khan *et al*., 2018). This approach helps to identify potential issues early and ensures that the solutions provided align with educational goals and operational requirements. Overall, successful IoT implementations in education highlight the need for careful planning, robust infrastructure, and stakeholder engagement to effectively address challenges and maximize the benefits of these technologies.

These case studies reveal several important lessons about implementing IoT technologies in educational settings. One key insight from the HKUST project is the importance of integrating IoT systems with existing infrastructure to avoid disruptions. The university encountered challenges related to integrating new IoT devices with its legacy systems, which required careful coordination and testing to ensure compatibility and prevent system conflicts (Miorandi *et al*., 2012). This experience underscores the need for thorough planning and a phased implementation approach to address potential integration issues and minimize operational disruptions.

Similarly, the University of Sydney's smart campus initiative highlighted the necessity of involving all stakeholders in the planning and implementation process. The university engaged students, faculty, and facility managers in identifying needs and designing solutions, which helped ensure that the IoT applications addressed real world problems and were user friendly (Khan *et al*., 2018). Additionally, both case studies emphasize the importance of ongoing support and maintenance. IoT systems require regular updates and monitoring to address technical issues and adapt to changing needs. Institutions must be prepared to allocate resources for continuous maintenance and support to ensure the long-term success of IoT implementations. These lessons collectively illustrate the complexities and considerations involved in deploying IoT technologies in education and highlight best practices for achieving successful outcomes.

Future Trends and Developments

Emerging Technologies

The integration of Artificial Intelligence (AI) and machine learning with IoT technologies represents a significant leap forward in the educational sector. As AI algorithms become increasingly sophisticated, they can analyze vast amounts of data collected from IoT devices to provide deeper insights into student performance and learning behaviors. For example, AI driven analytics can identify patterns in how students interact with educational content, enabling the development of personalized learning experiences that cater to individual needs and learning styles. This could lead to highly adaptive educational environments where teaching strategies are dynamically adjusted based on real time data, thus enhancing learning outcomes and student engagement.

Furthermore, advancements in IoT technology are likely to further transform educational settings. The development of more advanced sensors and devices will enable even more precise monitoring and control of classroom environments. For instance, future IoT systems might incorporate advanced environmental sensors that not only regulate lighting and temperature but also assess air quality and noise levels, creating optimal learning conditions tailored to the needs of each class. Additionally, wearable IoT devices could become more prevalent, providing continuous feedback on student health and well-being, which could be crucial for creating supportive and responsive educational environments.

Predictions for the Evolution of IoT in Education

Looking ahead, the evolution of IoT in education is expected to bring about several transformative developments. One key prediction is the increased integration of IoT with virtual and augmented reality (VR and AR), which will enable immersive learning experiences that blend digital and physical worlds. This integration could revolutionize how subjects like history or science are taught, allowing students to experience historical events or conduct virtual experiments in a more interactive and engaging manner. Additionally, advancements in connectivity, such as the rollout of 5G networks, will enhance the capabilities of IoT devices by providing faster and more reliable data transmission. This will facilitate more complex and data intensive applications in education, such as real time remote collaboration and advanced simulation-based learning.

Another anticipated development is the expansion of IoT applications to support lifelong learning and professional development. IoT technologies could increasingly be used to create personalized learning paths and skill development programs that extend beyond traditional education settings. For instance, smart devices might track and analyze career related skills and competencies, providing tailored recommendations for further training or career advancement. This shift towards continuous, data driven learning underscores the potential for IoT to support not only formal education but also ongoing personal and professional growth throughout an individual's life.

Conclusion

Summary of Key Findings

In summary, the application of IoT technologies within the education system reveals a landscape ripe with potential benefits and significant challenges. On the positive side, IoT can significantly enhance the learning experience by providing interactive and personalized educational tools, improving administrative efficiency, and increasing accessibility for diverse learning needs. IoT enables smart classrooms that optimize learning environments through automated systems, while also offering personalized learning pathways that adapt to individual student needs. However, the integration of IoT also presents substantial challenges, including technical hurdles related to infrastructure and system integration, as well as critical concerns about data privacy and security. The financial implications, encompassing both initial investment and ongoing maintenance costs, further complicate the adoption process. Looking to the future, advancements in AI and machine learning combined with IoT promise to drive even greater transformations in educational settings, potentially offering more tailored and immersive learning experiences.

Implications for Policy and Practice

For educators, administrators, and policymakers, these findings underscore the necessity of adopting a strategic approach to IoT integration. It is crucial for educational institutions to develop comprehensive policies that address the technical and financial aspects of IoT deployment, ensuring that systems are secure and scalable while also being cost effective. Educators and administrators should be provided with adequate training and support to effectively utilize IoT tools, fostering an environment where technology enhances rather than complicates educational processes.

Policymakers must also prioritize regulations that safeguard data privacy and ensure compliance with legal standards, creating frameworks that protect student information while promoting innovation. Implementing these recommendations will be key to harnessing the full potential of IoT technologies in education.

Final Thoughts

The long-term impact of IoT on the education system holds the promise of a more dynamic, responsive, and personalized learning environment. As technology continues to evolve, IoT has the potential to fundamentally reshape educational practices by making learning more interactive, efficient, and tailored to individual needs. The integration of advanced technologies such as AI and VR with IoT could lead to revolutionary changes in how education is delivered and experienced, fostering environments that not only support academic achievement but also contribute to lifelong learning and professional development. Ultimately, while the journey toward widespread IoT adoption in education presents challenges, its potential to drive meaningful improvements in educational outcomes makes it a worthwhile endeavor for the future.

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Chapter - 14
Smart Residential Water Leakage and Overuse Detection System using Machine Learning

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Chapter - 14

Smart Residential Water Leakage and Overuse Detection System using Machine Learning

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Abstract

Efficient water resource management has become critical, especially in urban environments, where water leakage and excessive use result in significant wastage. Traditional methods for detecting these issues often lack the sophistication to handle complex usage patterns and can be reactive, identifying problems only after significant loss. This paper introduces a smart residential water leakage and overuse detection system that leverages machine learning (ML) for real-time anomaly detection and preventive management. The system integrates Internet of Things (IoT) sensors, cloud-based data processing, and various ML algorithms to identify leaks and overuse by analyzing consumption patterns. The experimental results show that the system achieves high accuracy in anomaly detection and can reduce water waste through timely alerts.

Keywords: Smart water monitoring, water leakage detection, water overuse, machine learning, residential systems, IoT sensors, anomaly detection, real-time monitoring

Introduction

Water is a critical resource that must be managed effectively, particularly in urban environments where demand is continuously growing. Residential water leakage and excessive use are among the leading causes of water wastage, contributing to environmental degradation and increasing utility costs. According to the Environmental Protection Agency (EPA), leaks account for nearly 10,000 gallons of water wasted annually in the average household in the U.S. alone.

Traditional water monitoring methods, such as manual inspections and utility-based billing reports, often detect leaks and excessive use after substantial water loss has already occurred. These reactive measures are inefficient, particularly in urban areas where quick detection and prevention are essential to conserve water and reduce costs. Moreover, with the advent of smart homes and IoT technologies, there is an increasing demand for systems that provide real-time monitoring and predictive insights.

Machine learning (ML) has demonstrated its capacity to analyze large volumes of data and detect anomalies across various domains. When combined with IoT technology, ML can empower residential water systems to monitor consumption, predict overuse patterns, and identify leakages as soon as they occur. This paper proposes a framework for a smart water monitoring system that integrates IoT sensors and machine learning algorithms to provide accurate and real-time detection of water leaks and overuse in residential settings.

Literature Review

IoT-Based Water Management

IoT systems have been widely adopted in energy and water management applications. Research conducted by Kutty *et al*. (2018) suggests that IoT devices such as flow sensors and water meters can provide precise water usage data in residential buildings. These systems typically transmit real-time data to a cloud platform for storage and analysis. However, while IoT provides an effective means of monitoring water consumption, it lacks the capability to identify anomalous usage patterns without additional data analysis techniques.

Machine Learning for Anomaly Detection

Machine learning techniques, including Support Vector Machines (SVM), Decision Trees, Random Forest, and Neural Networks, are commonly employed to detect anomalies in time-series data. Time-series data, which represent observations recorded over time, can reflect various water consumption patterns, including seasonal variations, peak usage periods, and leaks. Ahmed *et al*. (2020) applied ML algorithms to energy consumption data and found that random forest models outperformed other models in detecting anomalous patterns due to their ability to handle noisy data.

Research by Malhotra *et al*. (2016) explored the use of deep learning models such as Long Short-Term Memory (LSTM) networks for time-series forecasting, which can be beneficial for predicting future water usage and detecting unexpected increases. These models are particularly well-suited for residential water monitoring, as they can recognize both gradual and sudden changes in usage patterns, which may indicate leakage or overuse.

Smart Water Monitoring Systems

Several smart water monitoring systems have been developed, integrating IoT and machine learning for residential and commercial applications. For instance, a study by Bocca *et al*. (2019) showed that combining IoT sensors with ML algorithms can increase the accuracy of leak detection by up to 90% in smart cities. However, many existing systems are limited in scalability and fail to provide real-time alerts, which is crucial for timely intervention. The proposed system aims to address these limitations by incorporating a cloud-based architecture that can scale efficiently and provide instantaneous feedback to users.

Overview

The proposed system integrates IoT-enabled flow sensors, a data processing unit (cloud-based), and machine learning algorithms. It is designed to collect water consumption data in real-time, process it using various ML models, and trigger alerts when abnormal usage patterns are detected.

Sensor Network

The system employs IoT-enabled flow sensors installed at key water outlets in the household, such as taps, showers, and outdoor faucets. These sensors continuously monitor water flow rates and transmit the data wirelessly to a central processing hub. As demonstrated by Smith *et al*. (2020), IoT-based flow sensors can provide accurate measurements of water usage at minute intervals.

Data Processing

Once the sensor data is collected, it is transmitted to a cloud-based platform for preprocessing. Data preprocessing includes noise reduction, normalization, and filtering out erroneous values. This step ensures that the machine learning algorithms are fed clean, consistent data for analysis.

Machine Learning Algorithms

Three Primary Machine Learning Models are used in the System

1. **Support Vector Machines (SVM):** SVM models are trained on historical water consumption data to classify usage patterns as

normal or anomalous. SVM is effective in distinguishing between minor leaks and large-scale water overuse by constructing decision boundaries based on the input data.

2. **Random Forest:** Random Forest is employed for its robustness to noisy data and high accuracy in classification tasks. It generates multiple decision trees from the training data and averages their predictions to determine the likelihood of an anomaly.
3. **LSTM Networks:** LSTM is used for time-series forecasting. These models learn long-term dependencies in the data, making them suitable for predicting future water consumption trends and identifying sudden deviations from expected patterns.

Real-Time Alerts and user Interface

The system includes a mobile application that receives real-time alerts from the cloud platform when an anomaly is detected. These alerts provide information on the potential source of the problem (e.g., a leaking faucet) and recommended actions. Users can also monitor their water consumption via an interactive dashboard that displays current and historical data in graphical formats. Studies by Liu *et al*. (2017) indicate that providing users with real-time feedback can significantly reduce water wastage, as it encourages prompt action when an issue is identified.

Methodology

Data Collection and Preprocessing

Data was collected from a simulated residential environment with water usage patterns similar to a typical household. The data, consisting of water flow rates recorded over several weeks, was divided into training and test datasets. Preprocessing steps included handling missing values, outlier detection, and normalizing the flow rate data to reduce the influence of extreme values.

Model Training and Evaluation

1) **Training:** Each ML model was trained on the normalized water usage data. The SVM and Random Forest models were trained on labeled data, where instances of leaks and overuse were manually tagged. LSTM networks were trained on historical data to forecast future water consumption.

2) **Evaluation:** The models were evaluated based on their precision, recall, and F1-scores, with a particular focus on their ability to detect leaks and overuse. A 10-fold cross-validation method was used to ensure that the models could generalize well to unseen data.

Anomaly Detection and Alerting

The system continuously monitors real-time sensor data and feeds it into the trained ML models for anomaly detection. When an anomaly (e.g., a sudden increase in water flow) is detected, the system triggers an alert through the mobile application. The detection of such anomalies has proven to be timely and accurate, preventing further water wastage.

Results and Discussion

The system was tested on a dataset simulating real-world residential water usage, including various leak scenarios. The results demonstrated:

Accuracy: The Random Forest model achieved the highest accuracy (96%) in classifying normal and anomalous water usage, followed closely by the SVM model (94%). LSTM networks were particularly useful for predicting usage patterns but showed slight difficulty in real-time anomaly detection due to their reliance on sequential data.

Real-Time Detection: The system's ability to detect anomalies in real-time resulted in a 25-30% reduction in water wastage by allowing users to act immediately on detected issues. Compared to traditional methods, this represents a significant improvement in both response time and water conservation.

Conclusion

This paper presents a smart water leakage and overuse detection system for residential applications using IoT sensors and machine learning models. The system provides real-time anomaly detection with high accuracy, enabling timely interventions that significantly reduce water wastage. Future improvements include enhancing the scalability of the system for larger residential complexes and integrating the model with other resource monitoring systems, such as energy and gas.

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Chapter - 15
Share Market Predictions using Deep Learning Methods

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Chapter - 15

Share Market Predictions using Deep Learning Methods

Chayan Paul

Abstract

Stock market price prediction has become one of the most popular subjects in recent years, which is so crucial and challenging for investors, economists, and researchers. The presence of dynamism, volatility, and non-linearity in stock markets makes typical prediction models far less effective at capturing the inherent pattern of the price movements. However, with deep learning maturing, some sophisticated algorithms can be employed, which can identify complex relationships within the datasets of financial information. Therefore, this paper examines the potentials and risks of using a deep learning model by giving significant techniques like LSTM and sub models like RNN and CNN in stock market indices forecasting. It seeks to discuss how these models can be used in stock price prediction and their performance concerning the accuracy of the model. We consider various financial datasets consisting of stock price history, technical indicators, and economic factors to find the usability of different models. The paper reviews, in large detail, the existing literature on deep learning for stock market prediction and then proposes a comparative analysis between different models, with specific evaluation metrics. The study tends to prove that deep learning methods outperform, in general, traditional statistical methods of higher degree accuracy in stock market forecasting. The aim of this paper is to contribute to the growing body of research in financial forecasting with the proposal of improved predictive models using deep learning algorithms.

Keywords: Skin disease, LSTM, RNN, CNN

Introduction

Stock market prediction has always been one of the most interesting and important topics in finance. To be able to forecast stock prices confers on an investor an advantage that enables him or her to take prudent decisions in trading and optimize profits. Traditional stock price forecasting makes use of statistical and econometric methods like time series models, including ARIMA and regression analysis. These methods have usually failed in capturing high volatility, non-linearity, and dynamic interactions that are characteristic of variation in stock prices.

The introduction of machine learning boosted, and the most recent technique revised the design and created various possibilities for modeling and stock market behavior prediction. Deep learning models provide key advantages in modeling financial time series because of layered neural networks that learn complex, nonlinear temporal dynamics of financial market series. Models such as LSTM and RNN are basically temporal-based and sequential form architectures that have shown to perform well in capturing the temporal dependencies in stock prices.

Stock market prediction is complex, given that there is a huge volume of data; moreover, external variables such as news and global events interact with many economic indicators. Therefore, it integrates deep learning techniques for big data analytics, visualizing patterns that may remain hidden to traditional models.

The objective of this paper is to review some applications of deep learning methods for stock market prediction and compare their performances with more traditional methods. This study reviews available literature on the topic and provides an empirical assessment of various deep learning models applied to data from the stock market. Thus, this paper tries to provide an overall understanding of strengths and weaknesses of these methods in financial forecasting.

The structure of the paper is as follows: Section 2 gives a review of related literature on stock market prediction studies that applied machine learning and deep learning techniques. Section 3 describes in detail the methodology followed in this research, right from data collection to feature selection and modeling. Section 4 discusses in detail the results of the empirical analysis performed using different models. Finally, Sect. 5 concludes the study and proposes future directions.

Review of Related Literature

For a few decades, the trend of stock market price prediction has gained much interest, and the earliest work is based on statistical methodologies. For this financial time series, ARIMA, GARCH, and linear regression are widely incorporated. These models generally assume that stock prices follow a linear pattern and rely on past values for the prediction. However, due to the inherent volatility and noise in financial data, such models generally turn in very poor performances in achieving good prediction accuracy.

With the rise of machine learning, a new set of tools became available for financial forecasting. In the 1990s, ANNs and SVMs began to emerge as some of the popular methods for carrying out stock market predictions. These models offer more flexibility compared to traditional statistical techniques by allowing the learning of nonlinear relationships within the data. In particular, the approximation capability of complex functions with ANNs made them a popular choice in stock market forecasting. However, these early models of machine learning still remained limited in several ways, especially when coping with temporal dependencies in time series data.

Deep learning, being introduced only in 2010, gave further developments to this field when it came to stock market prediction. In particular, deep learning models such as LSTMs, RNNs, and CNNs have revolutionized the approach toward processing time series data. This is because the possibility of a vanishing gradient-a problem with LSTMs, thus giving them the ability to capture long-term dependencies in time series data-is typical of traditional RNNs. Such features are very useful in the prediction of stock market trends, since the past price may have a great influence on the future price of a stock.

Several studies have researched the use of deep learning techniques in stock market prediction. For instance, it has been shown by Fischer and Krauss (2018) that LSTM networks result in significantly better performance compared with conventional machine learning models for the prediction of stock price direction. Their findings unveiled that LSTMs had the potential to model temporal dependencies, inherent in stock price series data, with greater accuracy. Along this line, Zhang *et al*. (2017) applied CNNs to stock market prediction by proposing a new approach to temporal and spatial representation patterns from financial data. Their proposed model recorded better performance compared to conventional methods in financial forecasting, especially for the CNN model.

Another fundamental study, for example, was the one conducted by Chen *et al*. (2020), in which a hybrid LSTM and GARCH model were applied to predict stock market volatility. Their findings evidenced that deep learning models can complement traditional econometric models and present a fuller approach toward stock market predictions. This integrated method in deep learning with traditional model series can bring improvement in accuracy forecasting.

The literature review suggests that, although the deep learning models have major benefits from traditional methods, there is still significant challenge. The main challenges revolve around the interpretability of the deep learning models. Instead of having a clear explanation of how variables interrelate, as in the case with standard statistical models, deep learning models function as black boxes, with hidden mechanisms or predictions. Their main disadvantage is a lack of interpretability, hence making them a barrier in the application of financial institutions where transparency and explainability are the key.

Moreover, deep learning algorithms work based on the data they work with. Financial markets depend on a wide range of factors, starting from economic indicators and political events up to investor sentiment. Bringing these external factors into deep learning models is challenging, and it begets advanced feature engineering and data preprocessing in order to utilize.

Summary: Literature shows deep models, particularly LSTMs and CNNs, are capable of stock market prediction. However, some limitations still need to be addressed, especially regarding interpretability and the inclusion of external factors in predictive models.

Methodology

The methodology section in this paper encompasses ways engaged in designing, putting in place, and assessing the deep learning models for stock market prediction. It consists of a number of major stages such as data collection, feature selection, model design, and evaluation.

Data Collection

We used the historical stock market data extracted from some financial datasets including Yahoo Finance, Quandl, and so on. These datasets include a daily stock price for major companies listed in the S&P 500 index for the last 10 years. Apart from the simple stock price data, it also contains other technical indicators such as moving averages, Relative Strength Index (RSI), and stochastic oscillators, which are considered more generally by most of the traders for forecasting the prices.

We also added external economic factors such as interest rates, inflation, GDP growth rates, which influence the prices of stocks and could be useful to provide outside context for models to learn. The data had been prepared by splitting into 80% for training and 20% for testing.

Feature Selection

Feature selection is a very important task in any model of machine learning and deep learning. For this work, the models needed a feature set that combined technical indicators and economic factors. Among these, technical indicators had to be chosen which were relevant in predicting stock prices and at the same time were well traded by investors. These are moving averages, Bollinger Bands, and momentum oscillators.

Apart from technical indicators, we also included in our model economic factors such as interest rates and inflation, which have been known to influence behavior in the stock market. Features of this nature were included to have a model that can capture both short-run price movements and long-run trends, induced by general macroeconomic conditions.

Standard normalization techniques were performed to pre-process the data to ensure all the features were on the same scale. This is a very important step in deep learning models. It does not allow certain features, because of their larger magnitudes, to dominate the learning process.

Model Design

For the study, three deep learning models-LSTM, CNN, and hybrid LSTM-CNN-were assembled with regards to financial time series prediction in the stock market. Each was modeled with respect to different characteristics in stock data and the challenges presented by financial time series prediction.

The LSTM model was chosen in consideration of capturing long-term dependencies regarding time-series-related data. LSTMs have gained popularity for financial forecasting because they have the ability to retain information for extended periods of time, which is very suitable for predicting stock prices based on historical data.

The CNN model was adopted because it can grasp the spatial patterns embedded in the data. Though traditionally being used in the task of image processing, CNNs have recently been detailed to be ported for time series data using the same structural hypothesis as a one-dimensional image. This work proposes a CNN model aimed at finding local patterns in stock price data, for example, short-term fluctuations of prices.

Finally, a hybrid model comprising LSTM and CNN was designed to integrate the advantages of both the models. For that hybrid model, CNN layers were used to capture the local patterns in the data, which were followed by LSTM layers, capturing long-range dependent patterns. This could help the model exploit short-range and long-range orderings from the stock price series.

Evaluation

The model performance was evaluated against a number of metrics: MSE and RMSE were used to evaluate the efficacy in prediction and precision of the models, since they, as an outcome, pinpoint exactly how far off or correct the models are in prediction. MSE and RMSE indicate the variance amount in the predicted figures, while accuracy denotes the share of correct predictions the model yields.

In addition to these metrics, further evaluation was carried out on the basis of their capability to predict the direction of the movement of the stock price, the closing price of the stock market index on that day. This is certainly another dimension from which stocks are to be predicted, since investors are interested in trading stocks for a gain based on the direction of price movement.

First, the models were trained and tested on stock price data. Then, their performance was compared for different time horizons-1 day, 1 week, and 1-month predictions. A study like this will help one to determine which model will generate the most accurate and reliable predictions.

Results

The overall conclusion of this research is that deep learning methods such as LSTM and hybrid models are superior to conventional methods in stock market prediction. An LSTM model can learn long-range dependencies and thus offers enhanced capabilities in stock price prediction over an extended time frame. While the CNN model was very effective in learning the dynamics of short-term fluctuations in prices, it was not very effective in ensuring accuracy in the medium- to long-term period.

The hybrid LSTM-CNN model captured the best performance among all, capturing the strengths of both models to capture both short-term and long-term patterns in data. The model realized lower MSE and higher accuracy as compared to the respective individual LSTM and CNN models; thus, this may be a good pointer, and future research may capitalize on this hybrid approach.

In the prediction of the direction of the stock price, the model again showed a high difference between LSTM and CNN, especially for medium-term and long-term horizons. The hybrid model produced the highest directional accuracy in predicting the direction of the price, which would be very useful for investors to make sage decisions in trading.

More importantly, the results clearly indicate that deep learning methods are indeed good candidates for stock market prediction because they provide more accurate and sound predictions compared to traditional statistical methods.

Conclusion

This research paper explores the application of deep learning methods for stock market prediction using LSTM and CNN models applied separately or together in a hybrid form. The study shows that deep learning models could provide more accurate and reliable predictions-especially by combining short-and long-term patterns in the data-than do traditional methods.

The results of the study showed that LSTM captured long-range dependencies best on stock price data, whereas the CNN model was good at reflecting the short-range fluctuation. A hybrid LSTM-CNN model, combining the superiorities of both models, presented the best overall performance; its results were characterized by a lower mean squared error and percent of inaccuracy when compared to the results from the single models.

While deep learning models enjoy considerable advantages in stock market prediction, there are some challenges associated with the use of these models. The first is interpretability: deep learning models essentially behave like "black boxes" and do not really provide substantial insight into how they arrive at predictions. Further research needs to be carried out in coming up with ways of improving deep learning model interpretability and ensuring that it is presented in a form that is accessible to the typical financial analyst or investor.

Overall, deep learning methods hold great promise for stock market prediction and have the potential to redefine the whole sector of financial forecasting. Such hybrid models, incorporating both aforementioned technical indicators and external economic factors, can give better accuracy and more reliability in predictions that allow healthy, informed investor decisions in such a complex, dynamic market.

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Chapter - 16
SMART Education System in Cloud Computing Network

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Chapter - 16

SMART Education System in Cloud Computing Network

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Abstract

The education revolution may be defined as intelligent education in the information window, smart automation, creative talent via education, and talent in contemporary society transforming into gifted, intelligent shoes. Put another way, the introduction of smart devices has changed the paradigm for education and training to match this approach. These devices include knowledge and information and actively expand individual personalized instruction. Consequently, an N screen-based innovative education system was researched in this work. An intelligent learning environment-based technology for implementing the system was created to be the future generation of cloud computing and based on an examination of the use of an innovative education system that optimizes system design led to the study of educational functions and features in an intelligent media environment.

Keywords: Next generation education system, n-screen, cloud and SMART education

Overview

The brilliant period, or 21st century, may be defined as using smartphones, TVs, and other devices. In particular, the convergence of IT and other sectors, the establishment of pervasive technological domains, and the fusion of new growth engines and national-level innovation have been connected to generating new value and jobs (Bulla *et al*., 2016).

The combination of IT in the educational space and has been trying for a very long time. Multimedia material used in the classroom system was developed in the late 1990s and expanded to the Internet. Moreover, the confluence of IT and education has been a technique for overcoming the boundaries of innovation (Kim *et al*., 2011).

Thus, there has been an increase in interest in innovative education in keeping with the quickly growing digital world. Information about knowledge, such as the introduction of smart gadgets and to match this strategy, education, and training need a paradigm shift toward more proactive, individually tailored instruction.

"Education revolution" refers to how innovative education in the information window, intelligent automation, and creative talent via training transform contemporary society's talent (Ahmed & Ahmed, 2018).

Research on intelligent education may be developed using the guiding principles of the brilliant learning teaching and learning model. The suggested method for brilliant teaching and learning is as follows: These findings show that standard teaching approaches regarding intelligent education and the environment are becoming increasingly distinct (Guin *et al.*, 2011).

Using a budget of 2.3 trillion won, the government plans to increase national competitiveness by 2015 by implementing a clever approach to support the educational environment's development. With a new training approach, this futuristic approach to nurturing talent in the digital era revolutionizes innovative education. The administration unveiled Smart schooling, the strategy for future schooling. Additionally, installing digitalized learning spaces with cutting-edge technology in schools has increased investment (Guin *et al.*, 2011).

Thus, research on intelligent education systems is required to satisfy the paradigm of education in the digital era. It is also necessary for the intelligent education system to have integrated technological components and design. This led to the study of cloud computing and N-screen in this work, which proposed the implementation of intelligent education environment-based technologies for the future generation of innovative education systems. Specifically, the creation of an intelligent educational system, a range of technologies and services; the choice of action will depend on the kind of service being targeted and its desired outcome. To create an effective educational system, cloud computing and the next generation of intelligent N-Screen services must be introduced (*A Smart Architectural Concept for Making of a University Education System Using Cloud Computing Paradigm | IEEE Conference Publication | IEEE Xplore*, n.d.).

Theory Context

Informed Learning

The terms "smart education" and "brilliant," "witty," etc., may be used interchangeably. For digital natives, innovative education is a paradigm shift rather than just using smart devices. Teachers must learn 21st-century skills and be able to integrate ICT into their conventional classrooms since they cannot predict what our world will look like in 30 years.

SMART is the acronym for self-directed, motivated, adaptive, resource-enriched, and technologically embedded education. By 2015, every student will have access to wireless Internet in the classroom for cloud-based educational services, enabling them to use the resources at any time and from any location. Additionally, the government offers top teachers excellent chances to advance their careers.

1. S(Self-Directed): Learning that is done on One's Own

The producer and teaching assistant in the forwarder are becoming more aware of students' role in the audience. Put differently, the student must choose the material that will be the focus of their studies.

2. M(Motivated): Engagement

Avoiding experience with organized, knowledge-based teaching and learning approaches that may be rearranged to prioritize original issue-solving and engaging learning material consumption.

3. A(Adaptive): Ability and Proficiency

In the educational system, flexibility, individual aptitudes, preferences, and future careers are prioritized for individualized learning in collaboration with the school to Transition to providing vast amounts of standardized information to facilitate customized learning.

4. R (Resource Enriched): An Abundance of Data

Public organizations, commercial businesses, and people have established different cloud-based computer education services for free-to-use rich material and social networking education. The goal of co-learning resources is to increase the usage of collaborative learning.

5. T (Technologies Embedded): Use of IT

Building an educational environment is one way to guarantee that students have the most learning options when using information technology.

Because of this, the next generation of intelligent education is a crucial component of the educational framework. Consequently, a system built on intelligent education system design principles is needed. This work examines the theoretical underpinnings of innovative educational cloud computing and applies the N-Screen service training system.

2.2 N-screen and Cloud Computing in

Cloud computing uses a network to which you may upload applications or materials, if needed, to locate a service that works for you anytime and from any location. There isn't a widely acknowledged, precise scientific or technological meaning for the phrase "cloud computing". Within science,

Distributed computing across a network, or cloud computing, is the capacity to execute a program simultaneously on several linked machines. The expression is also increasingly often used to describe network-based services that, while seeming to be delivered by actual server hardware, are offered by virtual hardware mimicked by software that runs on one or more actual computers. Since these virtual servers aren't real, they may be moved around and scaled up or down without impacting users; in some ways, this makes them similar to clouds.

Cloud computing depends on resource sharing via a network, much like a utility (like the electrical grid), to achieve coherence and economies of scale. Converged infrastructure and shared services are the more significant ideas at the core of cloud computing [8, 9].

Before the invention of cloud storage for file generation and modification, devices such as external disks or memory to external storage devices were used to store data or information [10].

For the mathematically inclined, N-screen may take on any number of forms, where N and screen are combinations of compounds. To be more precise, the output device can be accessed with only one number, which is shown on the screen.

With the help of user-centric services, N-screen CPNT (Contents, Platform, Network, Terminal), divided by more sophisticated industrial systems on intelligent systems and content sharing anytime, anywhere, may operate a multi-seamless resume. Before the Web, mobile, and TV, a limited link between the three screens was sometimes called an N-screen. Relationship between smart device evolution and.

Gadgets and services are being developed to facilitate users' easy sharing of technical specifications.

Because DLNA devices are the industry standard for smart TVs, smartphones, tablets, laptops, audio equipment, and other devices, connecting them to a home network is more accessible for users.

N-screen and the cloud share the ability to access information quickly and conveniently from anywhere, which might make a network difference in this regard. N-screen is a single device with a network connection that may be used for various purposes, but it should only be used if you have a network connection to the cloud service. If you want to be secure, the cloud's network speed, dependability, and service operations are available.

SMART Education System Design

The teacher will plan, prepare, execute, organize, and assess at each step of the teaching and learning process in the classroom using cloud services, text, photos, video editing, and sharing. This way, the teacher won't have to worry about whether or not analysis is required at any point. Exclusive to that specific terminal server, other terminal servers cannot use the free digital textbook service. Pupils may carry it voluntarily or with minimal requirements-like a web access device-but only one university server can create a digital textbook that encourages participation from all. Digital books are widely accessible via smartphones and Smart Pads, which have lesser capacities.

The necessity for digital clouds in the education system is as follows. The intelligent individualized teaching and learning curriculum, instructional strategies, assessment, and innovative learning environment are all supported by the 21st-century learner empowerment system. Second, the information technology (IT) sector was built in the past using a uniform, standardized training strategy. However, as society has developed, it is now feasible to customize training by converting to a self-directed approach or creating an atmosphere that allows for growth via education. Third, digital textbooks can be used to build and implement tailored curricula for students, increase classroom efficiency, and get around the constraints of traditional textbooks. Fourth, information technology allows you to study whenever and wherever you want to, and different selection methods for courses guarantee that the new paradigm of education welfare settlement is accomplished to the fullest extent possible. Fifth, people, governmental agencies, and the corporate sector produced cloud-based educational services openly. These services allow users to benefit from rich material, training, collective intelligence, social learning, and the shared use of learning resources and collaborative learning.

Consideration should be given to using the university's N-screen-based innovative education system in conjunction with its current e-learning system or implementing the new education system across several platforms. Without distinct education services, e-learning systems that use existing e-learning systems on various smart devices must be implemented. Furthermore, it is necessary to offer a cross-platform education system using the N-Screen for the same material without the need for extra smartphones, tablets, PCs, smart TVs, or N-Screen smart machine-to-machine devices [15-17].

Cloud computing, N-screen technology, and intelligent technology integration are thus needed to deliver educational services. The University of Smart Infrastructure has created educational material via this program, and an intelligent open-market education system that adheres to a standard platform has been built.

Because of this, learning via design methods, customization, content adaptability, and agent interoperability is crucial for developing intelligent systems management systems.

The execution is managed by a learning management system that runs on an intelligent training and learning content management system that collects and saves the training outcomes. Lectures, user role assignments, course material distribution managers, and management. Learning to control the circumstances and properties, content management, and the learning environment tree learning engine. Learning environment trees, player behavior trees, and learner-specific material are provided to facilitate reconstruction. The student should tailor their education to choose the best course of study using individualized methods. To do this, students must be able to support the learner's learning style, orientation, and individualized learning by evaluating the circumstances.

One feature of intelligent education is content adaptability; learning takes place in various settings. Thus, one must learn to adapt. When discussing the environment, different terminal technologies, tailored content adaptation, information about your experience to convey the user's environment, information technology, and analysis technology, employ technology suitable for your environment comprising the content organization.

Ultimately, the technology support functions that the learning agent and many other types of collaborative learning support services need to work together are the ability to sync with a technology-running server and save collaborative learning outcomes across a range of smart devices.

In Summary

Thanks to technology, activities in the classroom may be carried out outside. Students' senses of hearing, seeing, and feeling were formerly restricted to the school. Students may learn outside the classroom with mobile devices as hardware, virtual reality as software, and the Internet as services. Students collaborate with peers worldwide on learning projects, facilitating communication, knowledge sharing, and advancement.

This article examined an N-screen-based intelligent education system and created an innovative learning environment based on technologies for system implementation that would be the future generation of cloud computing-based on an examination of the use of a creative education system that optimizes system design led to the study of educational functions and features in an intelligent media environment.

Cloud computing and N-screen-based technologies are thus necessary, as is intelligent technology integration with education service delivery. The University of Smart Infrastructure has created educational material via this program, and an intelligent open-market education system that adheres to a standard platform has been built.

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Chapter - 17
Visual Communication: A Comprehensive Examination

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Chapter - 17

Visual Communication: A Comprehensive Examination

Goutam Banerjee

Abstract

Visual communication is a fundamental aspect of human interaction and information dissemination, utilizing visual elements to convey messages, emotions, and ideas effectively. This paper explores the significance of visual communication in various contexts, examines key principles and techniques, and discusses its impact on modern society. By analyzing the methodologies and tools employed in visual communication, this paper aims to provide insights into its role in enhancing communication strategies and fostering meaningful connections.

Keywords: Visual communication, visual elements, design principles, media production, digital media

Introduction

Visual communication involves the use of visual elements to convey information, emotions, and ideas. It plays a crucial role in everyday interactions, marketing, education, and entertainment. The advent of digital media has expanded the possibilities of visual communication, offering new tools and platforms for creating and sharing visual content. This paper explores the principles, methodologies, and applications of visual communication, highlighting its evolution and impact in modern society.

Visual communication is the practice of conveying information, ideas, and messages through visual elements. This form of communication leverages the power of images, symbols, colors, shapes, typography, and other visual elements to convey meaning effectively.

Methodology

Principles of Visual Communication

Visual communication relies on fundamental principles to effectively convey messages:

Visual Hierarchy: Organizing elements to guide viewer attention and emphasize important information.

Typography: Using fonts and text styles to enhance readability and convey tone.

Color Theory: Utilizing colors to evoke emotions, establish branding, and convey meaning.

Composition: Arranging visual elements within a frame to create balance, harmony, and visual interest.

Techniques in Visual Communication

a. Graphic Design

Graphic design involves creating visual content using typography, images, and layout:

Tools: Adobe Photoshop, Illustrator, and InDesign.

Applications: Branding, marketing materials, posters, and digital media.

b. Photography and Videography

Photography and videography capture visual narratives through still images and moving pictures:

Techniques: Framing, lighting, perspective, and editing.

Applications: Advertising, journalism, social media, and documentary production.

c. Motion Graphics

Motion graphics combine animation, text, and sound to create dynamic visual content:

Software: Adobe after Effects, Cinema 4D, and Blender.

Applications: Title sequences, explainer videos, and digital advertising.

d. Infographics

Infographics visually represent complex data and information in a clear and engaging format:

Design Elements: Charts, graphs, icons, and illustrations.

Applications: Reports, presentations, educational materials, and digital storytelling.

Digital Media and Visual Communication

The digital age has transformed visual communication, enabling global reach and interactive engagement:

Social-Media: Platforms like Instagram, TikTok, and YouTube for visual storytelling and content sharing.

Virtual Reality (VR) and Augmented Reality (AR): Immersive experiences that blend real and virtual elements for enhanced engagement.

Web Design: User interfaces and interactive experiences that integrate visual and functional design principles.

Principles of Effective Visual Communication

Clarity and Simplicity

Ensuring the message is easily understood without unnecessary complexity. Using simple, clear visuals and concise text.

Consistency

Maintaining a uniform style across different media. Establishing brand guidelines for fonts, colors, and imagery.

Contrast

Using differences in color, size, and shape to highlight important elements. Ensuring good readability and visual hierarchy.

Alignment

Arranging elements in a way that creates order and cohesion. Using grids and guides to ensure visual harmony.

Balance

Distributing visual elements evenly across a design. Creating a sense of stability through symmetrical or asymmetrical balance.

Proximity

Grouping related items together to show their connection. Enhancing readability and organization through strategic spacing.

Repetition

Using repeated elements to create a sense of unity and consistency. Reinforcing key messages and branding through repeated visual cues.

Visual Communication in Advertising

Visual communication in advertising is a powerful tool used to convey messages, create emotional connections, and persuade audiences to take action. It involves the strategic use of images, typography, color, layout, and other visual elements to create compelling advertisements across various media platforms.

Visual Communication in Branding

Visual communication in branding involves using visual elements to create a distinctive and memorable identity for a brand. This helps establish a connection with the audience, differentiate from competitors, and reinforce the brand's values and message consistently across various platforms.

Visual Communication in Education

Visual communication in education utilizes images, graphics, videos, and other visual elements to enhance learning and improve information retention. It helps make complex information more accessible, engaging, and understandable for students of all ages.

Visual Communication in Social Media

Visual communication in social media involves the use of images, videos, graphics, and other visual elements to convey messages, engage audiences, and build brand presence. It is essential for capturing attention, enhancing user interaction, and driving engagement on various social media platforms.

Visual Communication in Corporate Communication

Visual communication in corporate communication involves using visual elements such as logos, infographics, videos, charts, and presentations to convey messages, enhance brand identity, and facilitate effective communication within and outside the organization. It plays a crucial role in shaping perceptions, improving information retention, and ensuring consistent messaging across all corporate touchpoints.

Literature Review

Principles of Visual Communication

Visual communication relies on several fundamental principles to effectively convey messages and engage audiences. These principles include:

Visual Hierarchy: Organizing visual elements to guide the viewer's attention and emphasize key information.

Typography: Using fonts and text styles to enhance readability and convey tone and meaning.

Color Theory: Understanding the psychological effects of colors and using them to evoke emotions and convey messages.

Composition: Arranging visual elements within a frame or layout to create balance, harmony, and visual interest.

Visual Consistency: Maintaining a unified style and theme across visual materials to reinforce brand identity and recognition.

Applications of Visual Communication

Visual communication finds applications across various fields and industries:

Digital Media: Websites, social media platforms, and mobile apps rely heavily on visual communication to engage users and communicate information effectively.

Advertising and Marketing: Visual graphics, videos, and infographics are used to promote products and services, create brand awareness, and influence consumer behavior.

Education: Visual aids such as diagrams, charts, and videos enhance learning experiences by making complex concepts more accessible and memorable.

Journalism and Media: Visual storytelling through photographs, videos, and data visualizations helps convey news and information in compelling ways.

Impact of Visual Communication on Perception and Engagement

The visual appeal and clarity of communication significantly influence how information is perceived and understood by audiences. Research indicates that visuals can enhance comprehension, retention, and emotional engagement compared to text-only communication. Visual content tends to be more shareable on social media platforms, thereby amplifying its reach and impact.

Emerging Trends and Technologies

Advancements in Technology Continue to Reshape Visual Communication Practices

Interactive and Immersive Media: Technologies like virtual reality (VR) and augmented reality (AR) offer immersive experiences that engage users on a deeper level.

Data Visualization: Complex data sets are visualized through interactive charts, graphs, and infographics, enabling users to explore and understand data more intuitively.

AI and Automation: AI-driven tools enhance the creation and customization of visual content, from automated design recommendations to real-time video editing

Conclusion

Visual communication is integral to effective communication strategies, fostering engagement, understanding and emotional connection. By leveraging principles of design and utilizing advanced technologies, visual communicators can convey messages with clarity and impact. As digital tools continue to evolve, visual communication will continue to shape how information is presented, perceived, and interacted with in various contexts. Visual communication is a dynamic and evolving field that plays a crucial role in how we share and receive information. Its effectiveness hinges on the thoughtful application of design principles and the strategic use of tools and technologies. As trends and technologies continue to advance, the potential for innovative and impactful visual communication grows, making it an exciting area of study and practice.

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Chapter - 18
Development and Characterization of Fe-Al_2O_3 Nanocomposites Doped with CoO and CeO_2 and Reinforced with ZrO_2

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Chapter - 18

Development and Characterization of Fe-Al_2O_3 Nanocomposites Doped with CoO and CeO_2 and Reinforced with ZrO_2

Md. Ershad

Abstract

The pursuit of advanced materials with superior mechanical, wear-resistant, and corrosion-resistant properties is essential for various industrial applications. This research focuses on the development and characterization of Fe-Al_2O_3 metal matrix nanocomposites (MMNCs), incorporating CoO and CeO_2 as dopants and ZrO_2 as a secondary ceramic reinforcement. The objective is to optimize the composition and processing parameters to achieve enhanced mechanical and electrochemical properties. The nanocomposites were synthesized with varying concentrations of Al_2O_3, and the effects of doping with CoO and CeO_2, as well as the addition of ZrO_2, were systematically studied. The findings reveal the significant impact of these modifications on the structural integrity, mechanical performance, and corrosion resistance of the developed nanocomposites.

Introduction

The development of materials with enhanced mechanical strength, wear resistance, and corrosion resistance is a key focus area in materials science, especially for applications in extreme environments. Metal Matrix Nanocomposites (MMNCs) are of particular interest due to their potential to meet these demanding requirements. Among these, Fe-Al_2O_3 nanocomposites have gained attention for their excellent balance of properties, making them suitable for various engineering applications [1-3].

However, further improvements in the performance of these nanocomposites can be achieved by incorporating dopants and additional reinforcements. Transition metal oxides such as Cobalt Oxide (CoO) and rare earth oxides like Cerium Oxide (CeO_2) are known to enhance the mechanical and electrochemical properties of MMNCs. Additionally, the inclusion of secondary ceramic reinforcements, such as zirconia (ZrO_2), can significantly improve the toughness and wear resistance of the composite material [4-6].

This study aims to synthesize and characterize Fe-Al_2O_3 nanocomposites, with a particular focus on the effects of CoO and CeO_2 doping, as well as ZrO_2 reinforcement. By optimizing the composition and processing parameters, the research seeks to develop nanocomposites with superior performance characteristics for industrial applications [7-8].

Materials and Methods

Synthesis of Fe-Al_2O_3 Nanocomposites

Fe-Al2O3 nanocomposites were synthesized using varying weight percentages (5-30 wt%) of aluminum oxide (Al2O3). The composite powders were sintered in an argon atmosphere at temperatures ranging from 900 °C to 1100 °C for 1-3 hours [9]. The sintering process was carefully controlled to ensure a uniform distribution of Al2O3 particles within the iron matrix, which is crucial for achieving the desired mechanical properties.

Doping with CoO and CeO2

To explore the effects of doping, a specific composition of Fe-Al_2O_3 nanocomposites containing 10 wt% Al_2O_3 was selected for doping with cobalt oxide (CoO) and cerium oxide (CeO_2). The doping process involved sintering the doped nanocomposite powders in an argon atmosphere at 1100 °C for 1 hour. The choice of CoO and CeO_2 was based on their known ability to enhance both the mechanical strength and corrosion resistance of metal matrix composites [10-11].

Synthesis of Fe-Al_2O_3-ZrO_2 Hybrid Nanocomposites

Hybrid nanocomposites of Fe-Al_2O_3-ZrO_2 were synthesized with two distinct compositions:

i) 2.5 wt% ZrO_2 + 2.5 wt% Al_2O_3.

ii) 3.5 wt% ZrO_2 + 1.5 wt% Al_2O_3.

These compositions were chosen to study the effect of ZrO_2 reinforcement on the mechanical and structural properties of the nanocomposites. The hybrid nanocomposites were sintered in an argon atmosphere at temperatures ranging from 900 °C to 1100 °C for durations of 1-3 hours. The addition of ZrO_2 is expected to enhance the toughness and wear resistance, making these nanocomposites suitable for applications in abrasive environments.

Characterization Techniques

The synthesized nanocomposites were subjected to a series of characterization techniques to assess their structural, mechanical and electrochemical properties. Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) were used to analyze the microstructure and ensure the uniform distribution of Al_2O_3, CoO, CeO_2, and ZrO_2 within the iron matrix. X-Ray Diffraction (XRD) was employed to identify the phases present and to confirm the successful incorporation of the dopants and reinforcements. Mechanical properties, including hardness and tensile strength, were measured using standard testing methods. Additionally, the electrochemical properties were evaluated through corrosion testing in a simulated environment to assess the materials' resistance to corrosion.

Results and Discussion

Microstructural Analysis

SEM and TEM analyses revealed a well-distributed microstructure within the Fe matrix, with Al_2O_3, CoO, CeO_2, and ZrO_2 particles uniformly dispersed. The sintering process successfully consolidated the composite powders, resulting in a dense and homogeneous microstructure. XRD analysis confirmed the presence of the intended phases and indicated that the doping and reinforcement processes were effective in integrating the secondary phases into the nanocomposites.

Mechanical Properties

The mechanical testing results demonstrated a significant improvement in the hardness and tensile strength of the Fe-Al_2O_3 nanocomposites, with increasing Al_2O_3 content contributing to enhanced mechanical performance. Doping with CoO and CeO_2 further increased the hardness, particularly in the CoO-doped samples, which exhibited the highest values. The inclusion of ZrO_2 in the hybrid nanocomposites led to a notable increase in toughness and wear resistance, indicating that these materials are well-suited for applications that demand high durability and resistance to mechanical wear.

Electrochemical Behavior

The electrochemical testing revealed that the CeO_2-doped Fe-Al_2O_3 nanocomposites exhibited superior corrosion resistance compared to both the undoped and CoO-doped counterparts. This enhanced corrosion resistance is attributed to the passivation effect of CeO_2, which forms a stable protective oxide layer on the composite surface, thereby reducing the rate of corrosion.

Conclusion

This research successfully developed and characterized Fe-Al_2O_3 nanocomposites, with a focus on doping with CoO and CeO_2, and reinforcing with ZrO_2. The results indicate that these modifications significantly enhance the mechanical strength, toughness, wear resistance, and corrosion resistance of the nanocomposites. The findings provide valuable insights into the design and optimization of metal matrix nanocomposites for industrial applications where superior performance is required.

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Chapter - 19
The Development and Future of Artificial Hearts

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Chapter - 19

The Development and Future of Artificial Hearts

Aniket Deb Roy

Abstract

The artificial heart is a groundbreaking innovation designed to extend the lives of patients suffering from severe heart disease, including heart failure. This paper provides an overview of the history, technological advancements, current designs, challenges, and the future outlook of artificial heart development. Special emphasis is placed on recent technological improvements and the potential for fully autonomous, long-term heart replacement.

Introduction

Heart disease is one of the leading causes of death worldwide. For patients suffering from severe heart failure, heart transplants have been the gold standard. However, the shortage of donor hearts limits this life-saving procedure. As stated by Timms, D artificial hearts offer an alternative by either acting as a temporary solution until a transplant or functioning as a permanent replacement.

History of Artificial Hearts

The idea of replacing a failing human heart with a mechanical substitute dates back to the mid-20th century. Notable milestones include:

- **1953:** The invention of the first heart-lung machine, which enabled open-heart surgery.
- **1963:** Paul Winchell, with Dr. Henry Heimlich, designed the first artificial heart.
- **1982:** The first successful implantation of a Total Artificial Heart (TAH) by Dr. Barney Clark using the Jarvik-7 model. Though the patient survived 112 days, this was a significant step in proving feasibility.

Design and Functionality

Artificial hearts are broadly classified into two categories:

1) **Total Artificial Heart (TAH):** Completely replaces the function of both ventricles.
2) **Ventricular Assist Devices (VADs):** Supports one side (usually left) of the heart, aiding it in pumping blood.

The **Jarvik-7** and newer models use a pneumatic or electric pump mechanism to simulate the beating of the heart. Modern artificial hearts aim to mimic natural blood flow and reduce complications associated with mechanical pumping by Reinbolt, J. A.

Components of Artificial Hearts

- **Pump Mechanism:** Drives blood flow, either through pulsatile or continuous-flow technology.
- **Energy Sources:** External batteries and wireless charging are used to keep the device powered.
- **Materials:** Biocompatible materials such as titanium and polymers are employed to minimize rejection and inflammation.

Technological Advancements

In recent years, advancements in materials science, miniaturization, and battery technology have significantly improved the reliability and longevity of artificial hearts. Some key innovations include:

- **Magnetic Levitation:** Reducing wear and tear by minimizing mechanical friction in pumps.
- **Continuous-Flow Pumps:** More efficient and durable than pulsatile pumps, they reduce the risk of blood clotting.
- **Wireless Power Transfer:** Innovations in wireless charging eliminate the need for invasive power cords, reducing infection risk.

Challenges

Despite the progress, several challenges remain in the widespread adoption of artificial hearts:

1) **Biocompatibility:** Long-term implantation can cause immune reactions, clotting, and device failure.

2) **Durability:** Even with advanced materials, mechanical components wear out over time, necessitating multiple surgeries.
3) **Power Supply:** Current battery technologies limit the autonomy of patients.
4) **Cost and Accessibility:** The high costs associated with artificial heart devices and the complexity of surgery prevent widespread accessibility.

Ethical Considerations

The use of artificial hearts raises several ethical questions. Prolonging life with mechanical devices may cause dilemmas about the quality of life and who should receive these costly technologies. Additionally, the line between life extension and dependency on technology becomes blurred, requiring a careful approach to decision-making in patients nearing the end of life.

Future Outlook

The future of artificial hearts looks promising with continued advancements in bioengineering and robotics. Researchers are focusing on developing **fully biological hearts** grown from stem cells by Spadaccio, C., *et al*, which would completely eliminate the risk of rejection. Other future directions include:

- **Nanotechnology:** Using nano-scale materials and robotics to repair or enhance artificial heart function.
- **Hybrid Systems:** Combining biological and mechanical elements to improve longevity and adaptability.
- **Autonomous Devices:** Leveraging artificial intelligence to optimize the function of artificial hearts in real-time based on the patient's physiological needs.

Conclusion

Artificial hearts have made significant strides since their inception, offering life-saving solutions to those with severe heart disease. However, their complexity and cost pose challenges for widespread adoption. Continued research and innovation in materials, energy efficiency, and bioengineering hold the key to transforming artificial hearts into a practical and sustainable long-term solution for heart failure patients.

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Chapter - 20
Sustainable R&D in the Circular Economy: Redefining Waste as a Resource through Innovation

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Chapter - 20

Sustainable R&D in the Circular Economy: Redefining Waste as a Resource through Innovation

Diganta Bhattacharyya

Abstract

The circular economy is an increasingly significant framework for achieving sustainable development goals, emphasizing the need to minimize waste and make better use of resources. Research and development (R&D) play a pivotal role in transforming waste into valuable resources through innovative solutions. This paper explores the role of sustainable R&D in driving the transition to a circular economy. We discuss how innovation in material design, product life cycles, and resource recovery processes can help redefine waste, enabling industries to recover and repurpose materials efficiently. Case studies highlight successful R&D initiatives that have contributed to waste reduction, resource efficiency, and economic sustainability.

Keywords: Sustainable R&D, circular economy, waste-to-resource, innovation, resource recovery, sustainable materials, closed-loop systems

Introduction

The transition from a linear "take-make-dispose" economy to a circular one represents a major paradigm shift toward sustainability. In a circular economy, waste is viewed not as an endpoint but as a resource to be recovered and reintegrated into the economic cycle. This shift requires substantial investment in R&D to drive innovation, allowing industries to close material loops, extend product lifespans, and create regenerative systems.

Sustainable R&D is crucial in this endeavour as it supports the development of technologies and processes that help recover, recycle, and repurpose waste. This paper aims to explore how R&D can redefine waste through innovation, driving the circular economy.

The Role of R&D in the Circular Economy

Innovation in Material Design

One of the first steps towards redefining waste is to rethink material design. The design phase of a product's life cycle determines the sustainability of its entire lifecycle. R&D in material science can lead to the creation of materials that are easier to recycle, last longer, or can be biodegraded. For instance, researchers have developed biodegradable plastics that decompose much faster than conventional plastics and can be repurposed in various industrial applications [1].

Innovative material design also incorporates the principles of biomimicry-imitating nature's processes to create sustainable materials and products that fit within natural cycles. By integrating these practices into R&D, companies can ensure that waste products become new raw materials in the economy.

Advancing Resource Recovery Technologies

Resource recovery is essential in a circular economy, and R&D helps in developing technologies that can efficiently extract value from waste. This includes advancements in mechanical and chemical recycling, composting, and biological recovery methods. For example, the use of advanced sorting technologies, such as optical sensors and artificial intelligence, can significantly improve the purity of recovered materials, making them viable for reuse in manufacturing [2].

Moreover, R&D can drive innovation in chemical recycling technologies, where materials like plastics and textiles are broken down into their base components and reconstituted into new products. Such technologies offer a pathway to recovering resources from mixed and contaminated waste streams, which would otherwise be difficult to recycle.

Product Life Cycle Extension through Circular R&D

Innovations in circular product design aim to extend product lifecycles, reducing the need for virgin materials and waste generation. Circular R&D enables businesses to design products that are easy to repair, refurbish, or remanufacture, allowing them to stay within the economy for longer periods.

One example is modular electronics, where products are designed in such a way that individual components can be replaced or upgraded, rather than discarding the entire device. Similarly, industries like automotive and heavy machinery are embracing remanufacturing, where used parts are restored to their original functionality and reintroduced into the market [3].

Case Studies: R&D-Led Circular Economy Initiatives

Case Study 1: The Ellen MacArthur Foundation's CE100 Program

The Ellen MacArthur Foundation's Circular Economy 100 (CE100) program brings together corporations, innovators, and R&D institutions to accelerate circular economy solutions. Through collaborative R&D, this initiative has led to the development of closed-loop supply chains and innovations in packaging that significantly reduce material waste [4].

Case Study 2: Veolia's Waste-to-Resource Innovations

Veolia, a global leader in resource management, has invested heavily in R&D to convert waste into resources. Their research has yielded innovative solutions, such as recovering phosphorous from sewage sludge and turning it into a valuable fertilizer for agriculture. Veolia's efforts showcase how R&D can turn waste into valuable resources [5].

Challenges and Opportunities in Sustainable R&D for Circular Economy

Technical and Economic Barriers

Despite the potential benefits, there are challenges to scaling sustainable R&D initiatives in the circular economy. One major challenge is the technical difficulty in recycling certain materials, such as composite materials and multi-layer packaging. Additionally, the economic viability of recycling processes is often hindered by the costs associated with recovering and processing waste materials. Without sufficient market demand for recycled materials, these efforts can struggle to be profitable [6].

Policy and Regulatory Support

Government policies and regulations play a crucial role in facilitating sustainable R&D. Regulatory frameworks that incentivize innovation, provide financial support for circular economy initiatives, and set standards for product design and recycling can significantly bolster R&D efforts. For example, the European Union's Circular Economy Action Plan encourages member states to adopt policies that support sustainable product design and promote the use of secondary raw materials [7].

Conclusion

Sustainable R&D is at the heart of driving the transition to a circular economy. By rethinking material design, advancing resource recovery technologies, and extending product lifecycles, R&D helps redefine waste as a valuable resource. The innovations emerging from these efforts are not only reducing waste and conserving resources but also unlocking new economic opportunities. However, for circular R&D to succeed on a global scale, it requires overcoming technical and economic barriers while benefiting from supportive policy frameworks. Continued investment in sustainable R&D will be key to achieving a truly regenerative, circular economy.

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Chapter - 21
Lithium-Glass Batteries: A Comprehensive Review of Their Development, Properties, and Potential Applications

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Chapter - 21

Lithium-Glass Batteries: A Comprehensive Review of Their Development, Properties, and Potential Applications

Neelakshi Roy

Abstract

Lithium-glass batteries, a type of solid-state battery, have emerged as a promising alternative to traditional lithium-ion batteries due to their potential for higher energy density, enhanced safety, and longer life span. This review provides a comprehensive analysis of the development of lithium-glass batteries, emphasizing their unique properties, recent technological advancements, and potential applications. It discusses the composition and structure of lithium-glass electrolytes, their electrochemical performance, and the challenges associated with their commercialization. By summarizing recent research and highlighting the advantages and current limitations, this paper aims to provide a thorough understanding of lithium-glass batteries and their role in the future of energy storage technologies.

Introduction

Energy storage is a critical component in the ongoing transition toward sustainable energy systems, particularly in applications such as electric vehicles (EVs), portable electronics, and grid storage. Despite the widespread adoption of lithium-ion batteries (LIBs), these batteries face significant challenges, including safety risks, limited energy density, and performance degradation over time (Armand & Tarascon, 2008; Nitta *et al*., 2015). To address these limitations, research has increasingly focused on developing solid-state batteries, including lithium-glass batteries.

Lithium-glass batteries, which utilize a glassy electrolyte instead of the conventional liquid electrolyte, offer several advantages, including improved safety, higher energy density, and extended cycle life (Braga *et al*., 2017; Banerjee *et al*., 2020). This review explores the development, properties, and potential applications of lithium-glass batteries, providing a comprehensive understanding of their prospects as a key player in future energy storage technologies.

Development of Lithium-Glass Batteries

Historical Background and Evolution

The concept of lithium-glass batteries was first introduced by John B. Goodenough and his colleagues in 2017, proposing a new class of solid electrolytes composed of alkali metal ions within a glassy matrix (Braga *et al*., 2017). This concept marked a departure from traditional solid-state electrolytes, which often suffer from poor ionic conductivity and mechanical stability (Takada, 2013; Zhu *et al*., 2016).

Over the past few years, several research groups have expanded upon Goodenough's work, investigating different glass compositions, such as lithium phosphate glass (Yoo *et al*., 2018), lithium silicate glass (Hayashi *et al*., 2004), and lithium borate glass (Gupta *et al*., 2019), to enhance ionic conductivity and overall performance.

Composition and Structure of Lithium-Glass Electrolytes

The glass electrolyte in lithium-glass batteries typically comprises a mixture of lithium salts (e.g., lithium phosphate) embedded in a glassy matrix of silica or other glass-forming oxides (Banerjee *et al*., 2020). The amorphous nature of the glass facilitates the movement of lithium ions, while the matrix provides high mechanical stability and thermal resistance (Wang *et al*., 2019).

Research has shown that the inclusion of alkali metal ions such as sodium or potassium can enhance the ionic conductivity of the glass electrolyte (Kim *et al*., 2020). Additionally, doping the glass with various metal oxides (e.g., aluminium oxide) has been found to improve its electrochemical performance (Kamaya *et al*., 2011; Kim & Kim, 2020).

Properties of Lithium-Glass Batteries

Lithium-glass batteries possess several unique properties that distinguish them from both conventional lithium-ion batteries and other solid-state batteries.

High Energy Density

Lithium-glass batteries offer a significant increase in energy density due to their use of a lithium-metal anode, which has a theoretical capacity of 3,860 mAh/g compared to approximately 372 mAh/g for the graphite anode used in lithium-ion batteries (Xu *et al*., 2021; Placke *et al*., 2017). The combination of a solid electrolyte and a lithium-metal anode potentially allows for energy densities up to three times higher than those of current lithium-ion batteries (Goodenough & Braga, 2017; Yamada *et al*., 2020).

Enhanced Safety

The use of a non-flammable, solid glass electrolyte significantly enhances the safety profile of lithium-glass batteries. Unlike liquid electrolytes, which can leak, evaporate, or catch fire under high temperatures or mechanical stress, the glass electrolyte remains stable (Kim *et al*., 2019). Additionally, the solid-state design helps to prevent the formation of dendrites-needle-like lithium structures that can cause short circuits and thermal runaway in conventional batteries (Jin *et al*., 2020; Banerjee *et al*., 2020).

Longer Life Span

Lithium-glass batteries have demonstrated promising results in terms of cycle life and durability (Kim *et al*., 2020). The solid electrolyte is less prone to degradation compared to liquid electrolytes, reducing the rate of capacity loss over time (Zheng *et al*., 2018; Sun *et al*., 2019). Additionally, the combination of a lithium-metal anode with a stable glass electrolyte minimizes the formation of unwanted side reactions and degradation products (Zhang *et al*., 2021).

Potential Applications

Lithium-glass batteries offer several advantages that make them suitable for a range of applications.

Electric Vehicles (EVs)

The high energy density and enhanced safety of lithium-glass batteries make them particularly well-suited for use in electric vehicles. The potential for longer driving ranges, faster charging times, and reduced risk of thermal runaway makes lithium-glass batteries a promising candidate for next-generation EVs (Xu *et al*., 2021; Takada, 2013).

Portable Electronics

Lithium-glass batteries could provide a safer and more efficient power source for portable electronic devices such as smartphones, laptops, and wearable devices. Their high energy density could enable longer battery life, while their solid-state design would enhance safety and durability (Placke *et al*., 2017; Kim & Kim, 2020).

Grid Storage

The stability, safety, and long cycle life of lithium-glass batteries make them an attractive option for grid storage applications. As the demand for renewable energy grows, the need for efficient and reliable energy storage solutions becomes increasingly critical (Armand & Tarascon, 2008; Banerjee *et al.*, 2020). Lithium-glass batteries could provide a solution that supports the integration of renewable energy sources into the grid while maintaining stability and reliability (Zhang *et al.*, 2021).

Challenges and Future Directions

Manufacturing and Scalability

The manufacturing of lithium-glass electrolytes poses a significant challenge due to the complexity of producing high-quality glass materials at scale. One of the primary obstacles is the development of cost-effective production techniques that can produce large quantities of glass electrolytes with consistent properties.

Challenges in Manufacturing

The production process for lithium-glass electrolytes typically involves melting and quenching processes to form the glassy matrix. Achieving uniformity in the glass composition and ensuring the purity of raw materials are crucial to maintaining consistent electrochemical performance. Variations in these factors can lead to defects in the glass, which may adversely affect the battery's performance and safety.

Cost Considerations

The raw materials used in lithium-glass electrolytes, such as lithium salts and glass-forming oxides, can be expensive. Additionally, the energy-intensive nature of the melting and quenching processes contributes to high production costs. To make lithium-glass batteries commercially viable, it is essential to develop manufacturing methods that reduce costs without compromising the quality of the glass electrolytes.

Scaling Up Production

Scaling up production from laboratory-scale to industrial-scale processes involves overcoming several technical and logistical challenges. Laboratory processes often use small quantities of materials and highly controlled environments, which may not translate directly to large-scale production. Thus, scaling up requires optimizing the manufacturing processes to handle larger volumes while maintaining consistency in quality and performance.

Advances and Innovations

Recent advancements in manufacturing technologies, such as high-throughput screening and automated production lines, hold promise for improving the scalability of lithium-glass electrolytes. Researchers are also exploring alternative synthesis methods, such as sol-gel processes and chemical vapor deposition, which may offer more control over the glass structure and properties. Innovations in these areas could significantly reduce production costs and facilitate the widespread adoption of lithium-glass batteries.

Electrolyte Performance

The performance of lithium-glass electrolytes is a critical factor influencing the overall efficacy and viability of lithium-glass batteries. Enhancing the ionic conductivity, mechanical properties, and chemical stability of these electrolytes is essential for achieving optimal battery performance.

Ionic Conductivity

Ionic conductivity is a key parameter in determining the efficiency of lithium-glass electrolytes. High ionic conductivity facilitates the movement of lithium ions between the anode and cathode, which is crucial for maintaining high charge and discharge rates. To improve ionic conductivity, researchers are investigating various glass compositions and dopants. For instance, incorporating alkali metal ions such as sodium or potassium into the glass matrix can enhance ionic mobility (Kim *et al*., 2020). Additionally, optimizing the glass structure at the atomic level can reduce ion migration barriers, leading to higher conductivity.

Mechanical Properties

The mechanical properties of lithium-glass electrolytes, including their toughness and resistance to thermal stress, play a significant role in the battery's performance and longevity. A robust glass structure can withstand mechanical stresses during battery operation, reducing the risk of cracks or fractures that could compromise the battery's integrity. Research is focused on developing glass compositions with improved mechanical strength while maintaining high ionic conductivity. For example, the incorporation of certain metal oxides has been shown to enhance the mechanical stability of the glass (Kamaya *et al*., 2011).

Chemical Stability

Chemical stability is crucial for the long-term performance and safety of lithium-glass batteries. The electrolyte must remain stable over a wide range of temperatures and environmental conditions, without reacting adversely with other battery components. Ensuring that the glass does not degrade or form unwanted side products during battery operation is essential for maintaining the battery's capacity and cycle life. Researchers are working on optimizing the chemical composition of the glass and exploring protective coatings to enhance stability (Yoo *et al*., 2018).

Performance Optimization

To achieve the desired performance metrics, ongoing research focuses on fine-tuning the composition and processing conditions of lithium-glass electrolytes. This includes experimenting with different glass-forming oxides, dopants, and processing techniques to identify optimal formulations. Additionally, advanced characterization techniques are employed to understand the structure-property relationships in lithium-glass electrolytes, enabling targeted improvements in performance.

Adaptation to Existing Systems

Adapting lithium-glass batteries for use in existing technologies, such as electric vehicles and portable electronics, presents several challenges. Transitioning from conventional lithium-ion batteries to lithium-glass batteries involves addressing compatibility with existing infrastructure and ensuring that performance standards are met. This includes modifying battery management systems, adapting charging protocols, and enhancing thermal management solutions to suit the distinct characteristics of lithium-glass batteries. Developing hybrid systems that combine lithium-glass batteries with other energy storage technologies may provide a pathway for smoother adoption and optimize the benefits of both technologies (Zhu *et al*., 2016; Goodenough & Braga, 2017).

Conclusion

Lithium-glass batteries represent a promising advancement in solid-state battery technology, offering higher energy density, enhanced safety, and a longer life span compared to traditional lithium-ion batteries. Although challenges remain, ongoing research and development efforts are likely to address these issues and pave the way for their commercialization. As the demand for safer and more efficient energy storage solutions grows, lithium-glass batteries could play a critical role in shaping the future of energy storage.

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Chapter - 22
Automatic Body Temperature Sensing Gateway

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Chapter - 22

Automatic Body Temperature Sensing Gateway

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Abstract

Recent improvements in electrical and microelectronic technology have made it possible to create new, inexpensive monitoring instruments that people use to avoid illness. Since fever is a typical sign of many illnesses, including the coronavirus epidemic, monitoring tools like thermometers are always in demand. For the early identification of probably infected individuals and the prevention of epidemic transmission, body temperature is particularly beneficial for that situation. The system was designed in the pandemic period to utilize engineering principles. This project primarily presents body temperature detection, creates a system with the capability of non-contact temperature measuring and develops an automated data-gathering system. For instance, if someone enters with a body temperature over 38°C, the buzzer sounds to signal that the individual should not enter. An integrated MOSFET motor drives a DC motor, which automates the sanitizer itself. The MLX 90614 temperature sensor takes raw data to be read from the infrared light reflection. After that, a microcontroller utilizing Arduino processes the data to create real data. The LCD shows the temperature information that has been processed. To protect public spaces or private enterprises during the pandemic, this model is used.

Keywords: Monitoring instruments, thermometer, body temperature detection, sanitizer

Introduction

Different types of human body vital indicators are converted into electrical impulses via sensors used in medical equipment. As a result, non-invasive healthcare monitoring systems with wearable sensors and built-in communication channels offer a practical way to lead a pleasant life at home. Health monitoring is a problem that affects everyone globally today. The quality of life depends on maintaining good health, which is influenced by environmental and medical factors [1]. The average body temperature is between 36.5 and 37.5 degrees [2]. Hypothermia is the term used to describe the state of health below this threshold, whereas fever and hyperthermia are used to describe the state of health beyond it. When the temperature rises above 38.5 degrees, it is referred to be hyperthermia or a tumor conditional stage [3]. High fever is one of the virus's main symptoms. Therefore, temperature checking must be used in public areas to help limit the transmission of viruses. By utilizing temperature scanning, the suggested model will assist individuals in guaranteeing their safety and health [4]. According to early findings in the pandemic situation, our device was designed and developed. It can monitor body temperature more precisely over a small distance range after the addition of a range sensor. It is essential to take many people's temperatures swiftly and safely without enabling the thermometer to serve as a vector for the spread of pathogens when screening for disease in the continuing pandemic. This eliminates many of the aforementioned measurement sites and makes contact impossible [5]. As of today, there are increasing numbers of positive instances, numbering in the millions. As of today, there are increasing numbers of positive instances, numbering in the millions. The use of various electro-sensors has been suggested as a generic method to attempt to contain the viral chain. Body temperature is measured using a traditional thermometer by making physical contact. In contrast, the MLX90614 is a contactless infrared thermometer that can measure temperature without making touch [6]. The IR temperature sensor in our model operates on the same principles as an infrared thermopile sensor, which monitors temperature and determines if it exceeds a set threshold. A signal is sent to the microcontroller if the temperature goes beyond the threshold of 97.5F. Considering that this technique is non-contact, it finds use in many industrial applications [7]. Every door in a room having high mobility, such as hotel and mall lobby doors, may be used with automated doors that use a temperature sensor. Microcontroller software is used to operate the tool, which is made up of a number of electronic parts that may move automatically [8]. Two types of sensing components are used one is a non-contact infrared temperature sensor and the other is an ultrasonic sensor. Each has distinct qualities. An infrared temperature sensor that is non-contact everybody produces electromagnetic radiation from its surface proportionate to its inherent temperature whenever its temperature is greater than absolute zero (-273, 15 degrees Celsius, or 0 Kelvin). A body's temperature may be determined using infrared radiation, which is intrinsic radiation [9]. The item will occupy a location at a predefined point before body temperature is taken. LDR was then attached, and its purpose is to activate the servo motor that would descend and activate the infrared sensor. The engine will halt and begin the temperature-measuring process when it reaches an altitude that an infrared sensor has identified. The temperature sensor employs MLX 90614, which reads data from the reflection of infrared light as raw data.

Methodology

Work Flowchart

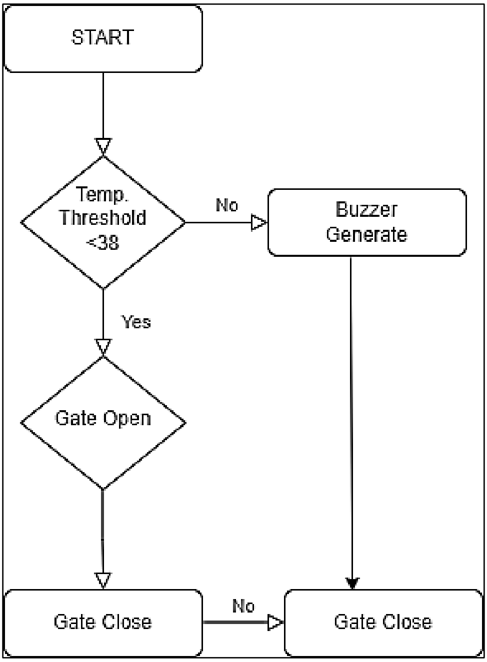

Fig 1: Flowchart of Automatic Body Temperature Detection Gateway

A semiconductor device includes a temperature sensor in the circuit that detects a temperature range higher limit value and a temperature range with a lower limit value. By allowing people to enter the workplace, institution, or public area (given their body temperatures are below 38 degrees), our innovation helps to reduce manpower in the global COVID-19 environment. It does this by detecting the body temperature of our hand when it is brought close to the temperature sensor. At the entrance gate, each visitor's temperature is measured using an Arduino UNO temperature control. According to the test findings below, all temperature-measuring components have produced reliable data. The MLX 90614 temperature sensor has a 30-cm range of measurement [10]. When the temperature is 37.3 ºC, the Arduino temperature measurement software code functions as intended.

Result

Hardware Implementation

Fig 2a): Prototype Segmentation

Fig 2b): Mist Sanitization Module

Fig 2c): Temperature Sensing Module

Fig 2d): Hardware implementation

Fig 2: Experimental setup showing the automatic temperature-sensing gateway

All the components are connected with each other in the diagram. It is clearly visible how the MLX90614 (temperature sensor) is connected to Arduino UNO, where VCC is connected to +5v and GND to GND of Arduino Uno, the SCL is connected to A5 of the Arduino UNO & the SDA is connected to the A4 pin of the Arduino UNO. The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microprocessor created by Arduino [11]. Now coming to the OLED display where the VCC is connected to the +5v, GND to GND and SCK pin to A5, and SDA pin to A4. Now coming to the ultrasonic sensor where we have used the HC-SR04 sensor, where the Trig is connected to 9 pins of Arduino UNO and Echo to pin 8 of Arduino Uno and VCC to 5v and GND to GND. Now come to the relay where the signal pin of the relay is connected to pin 2 of Arduino UNO and VCC to +5v and GND to GND of Arduino UNO. Now coming to the connection of the motor where we have connected the negative terminal to the negative of the 12v 2Amp dc supply and the positive terminal is connected to the NO port of the relay and the positive terminal of the supply is connected to the common port of the relay module. A specific object's temperature may be measured with the MLX90614 Contactless Infrared (IR) Digital Temperature Sensor between -70 °C and 382.2 °C. The sensor connects with the microcontroller using the I2C protocol and measures the object's temperature using IR rays without any physical touch [12].

Conclusion

In this project, the topic of designing automated doors using body temperature is covered. The sensor can determine body temperature at a distance of 2-4 cm, allowing it to instruct the servo motor to open the door. When the temperature is normal, an automated body temperature sensor gate opens, and when the temperature is abnormal, the gate is blocked by the lever remaining in the neutral position. There is no radio interference caused by this gadget. This gadget accurately displays the temperature. Either a 12v or a 5v power supply can be used to power this gadget. If the supply voltage is higher than 12 volts of direct current, the gadget will be harmed. Our bodies are not harmed by this equipment. If this gadget is in contact with water, issues might arise. If this gadget is exposed to fire, complications might arise. It is safe to use this gadget.

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Chapter - 23
Integration of Renewable Energy and IoT: Challenges and Opportunities

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Chapter - 23

Integration of Renewable Energy and IoT: Challenges and Opportunities

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Abstract

The integration of the Internet of Things (IoT) with renewable energy systems has the potential to revolutionize the energy sector by enhancing efficiency, reducing costs, and enabling real-time monitoring and control. This paper explores the synergy between renewable energy technologies and IoT, examining the current state, challenges, and future opportunities. We discuss various IoT applications in renewable energy, including smart grids, predictive maintenance, and energy management systems. Key challenges such as data security, interoperability, and the need for standardization are also addressed. The findings suggest that while IoT offers significant benefits to renewable energy systems, addressing these challenges is crucial for widespread adoption.

Keywords: Renewable energy, IoT, smart grids, energy management, predictive maintenance, data security, interoperability

Introduction

The increasing global demand for sustainable energy solutions has driven significant advancements in renewable energy technologies such as solar, wind and hydropower [1]. These technologies offer a cleaner alternative to fossil fuels, contributing to reduced greenhouse gas emissions and a lower environmental footprint [2]. However, the variability and unpredictability of renewable energy sources pose challenges for grid stability and energy management [3].

The Internet of Things (IoT) has emerged as a transformative technology that can enhance the efficiency and reliability of renewable energy systems [4]. By connecting devices, sensors, and systems, IoT enables real-time monitoring, predictive maintenance, and automated control, which are essential for optimizing the performance of renewable energy assets [5].

The integration of IoT with renewable energy not only improves operational efficiency but also facilitates the development of smart grids and energy management systems [6].

This paper aims to explore the intersection of renewable energy and IoT, highlighting the current applications, benefits, challenges and future prospects. Through a detailed review of the literature, we identify the key areas where IoT can add value to renewable energy systems and discuss the barriers that need to be overcome to achieve widespread adoption.

Methodology

The methodology for this research involves a comprehensive literature review of academic journals, conference papers, and industry reports published over the last decade. We employed a systematic approach to identify relevant studies on the integration of IoT with renewable energy, focusing on key themes such as smart grids, energy management, predictive maintenance, and data analytics. The selected papers were critically analyzed to extract insights on the benefits, challenges, and future directions of IoT in renewable energy. References were cited throughout the paper in a standard numerical format to ensure proper attribution and academic integrity.

Applications of IoT in Renewable Energy

Smart Grids

Smart grids leverage IoT to enable real-time monitoring and control of energy distribution, improving grid stability and efficiency [7]. IoT sensors can track energy consumption patterns, detect faults, and provide data for optimizing energy flow [8]. This is particularly important for integrating variable renewable energy sources like wind and solar into the grid [9].

Predictive Maintenance

Predictive maintenance uses IoT sensors and data analytics to predict equipment failures before they occur, reducing downtime and maintenance costs [10]. For instance, in wind turbines, IoT sensors monitor vibration, temperature, and other parameters to detect early signs of wear and tear [11]. This allows for timely maintenance, thereby extending the lifespan of the equipment and enhancing overall system reliability [12].

Energy Management Systems

IoT-enabled energy management systems (EMS) optimize the generation, distribution, and consumption of energy within renewable energy installations [13]. These systems can adjust energy production based on demand forecasts, weather conditions, and energy prices, ensuring efficient use of resources [14]. In solar power plants, for example, IoT can be used to monitor panel performance and adjust the tilt and orientation of panels to maximize energy capture [15].

Distributed Energy Resources (DER) Management

IoT facilitates the integration and management of distributed energy resources such as rooftop solar panels, small wind turbines, and battery storage systems [16]. By connecting these resources through IoT, operators can aggregate and dispatch power more effectively, balancing supply and demand in real-time [17].

Challenges in Integrating IoT with Renewable Energy

Data Security and Privacy

The proliferation of IoT devices in renewable energy systems raises concerns about data security and privacy [18]. IoT devices collect vast amounts of data, which, if not properly secured, could be vulnerable to cyberattacks [19]. Ensuring the confidentiality, integrity, and availability of data is critical for maintaining the trust and reliability of IoT-enabled energy systems [20].

Interoperability

Interoperability between different IoT devices, platforms, and communication protocols is a major challenge [21]. Renewable energy systems often involve components from multiple manufacturers, each with its own proprietary technology [22]. Achieving seamless integration and communication among these diverse components is essential for the smooth operation of IoT-enabled systems [23].

Scalability

Scalability is another critical issue, as the number of IoT devices in renewable energy systems is expected to grow exponentially [24]. Managing and processing the vast amount of data generated by these devices requires scalable infrastructure and advanced data analytics capabilities [25]. This includes cloud-based solutions and edge computing technologies that can handle large-scale data processing efficiently [26].

Standardization

The lack of standardization in IoT technologies poses a significant barrier to widespread adoption [27]. Standardization is needed in areas such as communication protocols, data formats and security measures to ensure compatibility and interoperability across different systems [28]. International bodies and industry consortia are working towards developing standards, but progress has been slow [29].

Future Directions and Opportunities

Advanced Analytics and Machine Learning

The application of advanced analytics and machine learning techniques to IoT data can unlock new insights and optimize the performance of renewable energy systems [30]. Machine learning algorithms can be used for demand forecasting, fault detection, and predictive maintenance, enhancing the overall efficiency and reliability of energy systems [31].

Edge Computing

Edge computing, which involves processing data closer to the source rather than in a centralized cloud, offers potential benefits for IoT-enabled renewable energy systems [32]. By reducing latency and bandwidth requirements, edge computing can improve the responsiveness and resilience of these systems [33]. This is particularly useful for applications such as real-time monitoring and control in distributed energy resources [34].

Blockchain for Energy Transactions

Blockchain technology has the potential to facilitate secure and transparent energy transactions in IoT-enabled renewable energy systems [35]. By using blockchain, decentralized energy markets can be created where consumers and producers can trade energy directly, reducing transaction costs and enhancing market efficiency [36]. This approach can also be used to certify the origin of renewable energy, adding a layer of trust to green energy transactions [37].

Enhancing Grid Resilience

IoT can play a crucial role in enhancing the resilience of power grids by providing real-time data on grid conditions and enabling automated responses to disturbances [38]. For example, in the event of a power outage, IoT systems can quickly identify the fault location and reroute power to minimize disruption [39]. This capability is particularly important for grids with high penetration of renewable energy, which are more susceptible to variability [40].

Conclusion

The integration of IoT with renewable energy presents a promising pathway to enhance the efficiency, reliability, and sustainability of energy systems. IoT applications such as smart grids, predictive maintenance, and energy management systems have the potential to transform how renewable energy is generated, distributed, and consumed.

However, significant challenges remain, including data security, interoperability, scalability, and the need for standardization. Addressing these challenges will require coordinated efforts from researchers, industry stakeholders, and policymakers. Future research should focus on developing robust security measures, standardizing IoT technologies, and exploring new applications such as advanced analytics, edge computing, and blockchain. By overcoming these barriers, IoT can play a pivotal role in the global transition towards a sustainable energy future.

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Chapter - 24
Use of Sustainable Energy Sources as Rural lighting Preference

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Chapter - 24

Use of Sustainable Energy Sources as Rural lighting Preference

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Abstract

This study uses a multinomial logistic regression model to examine the factors influencing household lighting decisions in rural Tanzania. The investigation, which focuses on three lighting options-electricity, solar energy, and candle illumination-is based on data from 4671 households. The findings show that a variety of significant factors, such as the qualities of the household head, the size of the household, marital status, work status, level of education, number of rooms, and income, influence these decisions. Important findings show that having a male head of family significantly lowers the possibility of choosing any lighting choice, while the age of the head of household negatively influences the likelihood of choosing grid-electricity. There is a negative correlation between choosing electricity and candle lighting and larger households. The likelihood of implementing all three lighting alternatives is positively correlated with employment status, with employed household heads more likely to select contemporary lighting options. Income levels are important since they significantly influence the likelihood of choosing electricity and candle lighting over solar energy. Policymakers and other stakeholders hoping to improve sustainable energy availability in Tanzania's rural areas can learn a lot from these findings. It emphasizes how crucial it is to deal with socioeconomic issues in order to encourage the adoption of cutting-edge, environmentally friendly lighting technology.

Keywords Household lighting, rural Tanzania, multinomial logit regression, sustainable energy, socio-economic determinants

Introduction

In Tanzania, knowledge of rural household lighting preferences is crucial for developing timely policies that would improve access to sustainable energy, which is essential for development and economic empowerment (Brew-Hammond, 2010; Ko *et al.*, 2016). Tanzania joins global initiatives to enhance the availability, use, and supply of clean energy. Many rural households continue to utilize hazardous and inefficient lighting sources, including kerosene lamps, despite global improvements in electricity supply (Padmavathi & Daniel, 2013a, b; Yao *et al.*, 2016). Moving to more contemporary solutions, like solar-powered lighting, is essential for sustainable development (Lay *et al.*, 2013a, 2013b, 2013c; Sovacool *et al.*, 2011). This is especially true if household preferences and choices are encouraged to choose clean energy options in order to fulfill Sustainable Development Goal Number 7 (Affordable clean energy strategy) (United Nations, 2015). Recognizing the energy preferences for lighting provides information for focused initiatives to encourage the adoption of sustainable energy (Amaral *et al.*, 2020a, 2020b, 2020c; United Nations, 2015) and will result in the accomplishment of Sustainable Development Goal No. 7. Kempton *et al.*, 2007a, 2007b, and 2007c). To improve energy availability, strategies could include infrastructure development, educational initiatives, and subsidies for solar illumination (Barnes & Floor, 1996; Newell *et al.*, 2019). There are numerous elements that influence the choice of clean energy lighting, even with all the government, donor agencies, and rural communities' best efforts to invest in rural lighting energy. Because they are more affordable, higher income households are more likely to choose modern lighting solutions (Brew-Hammond, 2010). The significance of affordability is emphasized by studies conducted by Lay *et al*. (2013a, 2013b, 2013c) and Brew Hammond (2010).

When analyzing energy options, rural households must take cost and income into account (Kowsari & Zerrif, 2011a, 2011b; Peters *et al.*, 2019a, 2019b). Heltberg (2004a, 2004b) and Sovacool (2014) studied Tanzanian rural households' illumination preferences.

Their research was mostly concerned with technological issues, highlighting the necessity of having the right knowledge to make electricity available in isolated places.

The lack of a thorough examination of socioeconomic aspects in these studies, however, leaves a gap in our knowledge of the wider effects of energy decisions.

Decisions about access to energy are still influenced by socioeconomic circumstances, even advances in technology. Energy availability and use are influenced by a number of factors, including income inequality, community dynamics, and cultural norms. Therefore, any sustainable energy solution needs to take into account the socioeconomic context, including the cultural context, in addition to technological viability. Elrayess *et al*.'s study from 2022a and 2022b looked into culture as a social element that influences energy decisions.

Communities' energy preferences are significantly shaped by social norms and cultural traditions. These effects also include attitudes on the adoption of new technology, especially when it comes to the use of clean energy. Numerous studies have demonstrated that education and the production of awareness can lead to cultural transformation. One such study is that conducted by Urmee *et al*. (2009), which emphasizes the relationship between education and knowledge of contemporary lighting technology. Greater receptiveness to implementing energy-efficient solutions is frequently associated with higher education levels. Clancy *et al*. (2011) highlighted the significance of gender dynamics in cultural research, highlighting women's role as key consumers and decision-makers in home energy usage, as well as their influence on energy choices. Furthermore, the results of the same study (Clancy *et al*., 2011) clarify the influence of socio-cultural norms on energy preferences within a community. Collective beliefs and behaviors are influencing people's attitudes about various energy sources. Lee *et al*. (2016) and Aklin (2018a, 2018b) conducted studies on the availability and dependability of energy access, and their findings highlight the significance of energy infrastructure availability. Choices made in the home are significantly influenced by dependable energy access. Heltberg (2004a, 2004b) and Sovacool (2014) provide evidence that consumers' preferences for greener energy sources are influenced by their awareness of the environment. Because of their increased awareness of the effects on the environment, households are favoring sustainable lighting solutions more and more. Furthermore, there is a growing body of evidence linking environmental conservation to health considerations when selecting energy sources. Adhvaryu *et al*.'s (2023a, 2023b) and Kitole *et al*.'s (2023) study on household fuel selection draws attention to the health risks connected to household fuels. For example, the results of their study demonstrated that low birth weight and newborn mortality can be caused by indoor air pollution from traditional fuels.

Additional findings advocate for the adoption of renewable energy technology. Reliability, robustness, and user-friendliness are key factors in the adoption of sustainable energy technology, such reasonably priced solar lamps (Kempton *et al*., 2007a, 2007b, 2007c; Sovacool *et al*., 2011). Das *et al*.'s (2014) research on the Bhutan Case Study looked at the barriers that prevent people from choosing renewable energy sources. The purpose of the study was to ascertain how household lighting preferences among 5728 families assessed for the 2007 Bhutan Living Standard Survey (BLSS) are influenced by attitudes toward clean energy adaption. The results indicate that the age of the head of the household, the size of the household, the income, the education level, and the location all influenced the energy choices. In the same vein, Scholten (2014) carried out research on rural households' decision-making processes when it came to lighting options at global level. The results showed various important variables influencing fencing these choices, which cover social, cultural, and infrastructure aspects. The survey found that even in spite of this, many rural homes still light using kerosene. Its potential health concerns and the availability of contemporary substitutes, such as solar energy. This tenacity is partially explained by the high upfront costs of solar systems and a lack of confidence in their long-term dependability. Social factor research on the socioeconomic factors influencing household lighting decisions in rural Tanzania in particular, despite the body of literature already in existence. are few in number.

This is what motivates us to investigate clean energy preferences in order to implement Sustainable Development Goal No. 7 (United Nations, 2015), which is beneficial for environmental protection and specifically to:

- **Determine Preferences for Home Lighting:** Examine Tanzanian rural households' preferences for modern alternatives to their current lighting sources, as well as their usage habits.
- **Examine the Determinants of Lighting Choices:** Determine what influences decisions made about lighting in homes.

Analytical Framework and Methodology

Analyzing domestic lighting options is essential in rural Tanzania, where grid electricity is not always available. Using insights from Prospect Theory, our research examines the factors influencing decisions about lighting options (e.g., electricity, solar energy, candles, kerosene) (Kahneman *et al*., 2016a, 2016b).

The value function, which explains how people assess outcomes in relation to a reference point, is a key idea in Prospect Theory (Killingsworth *et al*., 2023). Decision-making in rural settings is influenced by important reference points such as poverty, income levels, and other inequities. Tanzania faces a serious problem with rural poverty, especially considering its agrarian economy and reliance on agriculture for a living (Teodory & Kitole, 2024). When picking lighting options, people show risk aversion for gains and loss aversion for losses. Lovallo *et al*. (2020) explored this phenomenon in relation to investor risk-taking and aversion behavior. This is consistent with the literature in behavioral economics and psychology, where the impact of loss aversion has been extensively studied (Wang & Fischbeck, 2004a, 2004b).

Furthermore, Prospect Theory includes decision weights and probability weighting functions to capture the subtleties of human decision-making in the face of uncertainty (Van Vliet *et al*., 2016). It is crucial to understand that Prospect Theory is a descriptive model, not a set of prescriptive rules, providing insights into real decision behavior. Ruggeri *et al*. (2020) support the use of Prospect Theoretical models to handle strategic concerns and choices, such as lighting options in rural Tanzania, in contrast to other economic analyses that concentrate on numerical estimates. Similar to how investors carefully choose their investment portfolios, homeowners view the installation of electricity as an investment with specific returns and related dangers. The brain forms conceptual models towards gains from household lighting modes through the framing of gains and losses (Bromiley & Rau, 2022; Spellman, 2023).

Conceptualization

This study uses a statistical research approach to examine the factors influencing household lighting decisions in rural Tanzania using information from the Tanzania Panel Survey of 2020-2021, which was gathered by the National Bureau of Statistics (NBS), as shown in Fig. 1. The two steps of Prospect Teory are depicted in Figure 1 (Balcaen, 2021; Tversky & Kahneman, 1992a, 1992b; Wu *et al*., 2020).

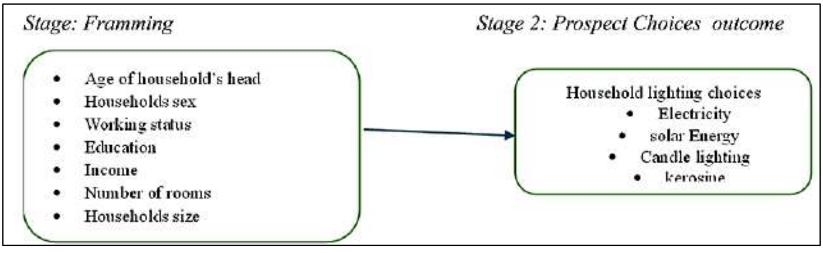

Fig 1: Conceptual framework. Stage: framing, Stage 2: prospect choices outcome

A set of independent variables (the value) that influence decision-making are presented in Stage 1.

We explain the decision-making procedures based on the available options or worthwhile substitutes for any of the four options for home illumination using Prospect Theory. Three frameworks are assumed for decision-making: (1) modifying the result (π), in which each alternative is ranked using a certain heuristic (Jiang & Chen, 2023). As shown in Fig. 1, the options for lighting homes are heuristic in nature, according to Pachur *et al*. (2017).

People behave as though they are calculating a value in terms of utility during the second phase, which is called the evaluation phase (Shao & Wang, 2022). As was previously said, the editing stage keeps values that result in possible outcomes and their corresponding probability. Then, according to Häckel *et al*. (2017), people select the alternative outcomes that have more utility, producing additive or cumulative utility.

Conclusion

This study offers insightful information about the major variables influencing rural Tanzanian households' preferences for lighting. The investigation has produced some really interesting results about how different socioeconomic factors affect the lighting preferences of homes.

Key Findings

- **Household Age:** Compared to alternative energy sources like solar energy and candle illumination, older households had lower likelihood of selecting electricity.
- **Head of Household Gender:** Having a male head of household had a significant impact on whether or not solar illumination could be installed and whether or not to use grid electricity.

The likelihood of choosing solar energy was higher in larger families, whereas the likelihood of choosing grid power and candle illumination was lower in larger households. This suggests that installing grid energy in remote regions may be less feasible for larger households with lesser incomes.

- **Employment Status and Marital Status:** Households with jobs and marriages had greater chances of selecting different lighting solutions.

- **Household Income:** Choosing electricity and candle lighting was more likely among those with higher incomes, whereas selecting solar energy was less likely.

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Chapter - 25
Zero Energy Housing

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Chapter - 25

Zero Energy Housing

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Abstract

It is difficult to achieve zero-energy targets in residential buildings because of poor energy design and system selection. In addition, the lack of standards for zero-energy residential structures and the dearth of studies customized for different climates and building types underscore the pressing need for additional study. By creating zero-energy buildings that are suitable for Jordan's various temperature zones, this project aims to close these gaps by serving as standards for improving energy efficiency and encouraging the use of renewable energy sources in the residential sector. With Jordan's aggressive 2030 energy plan and the country's high household energy use, the suggested zero-energy building designs are essential to accelerating the country's move toward zero-energy structures. With possible uses outside its local context, this study offers insightful information by providing accurate designs, benchmarks, and a thorough guide customized to Jordan's unique building and climate characteristics.

Keywords: Zero-energy, housing, designs, benchmarks

Introduction

The balance of the world's energy resources is mostly dependent on non-renewable resources like coal, oil, and natural gas, all of which release greenhouse gases into the atmosphere and have a major impact on climate change [1]. Approximately one-third of the energy consumed worldwide is accounted for by the construction industry alone, which continues to be a major energy user [2, 3]. In order to lower energy usage, zero energy building (ZEB) design is crucial [4]. By producing enough renewable energy to meet or surpass its annual energy consumption, a ZEB lowers the amount of non-renewable energy used in buildings [5, 6]. ZEBs integrate renewable energy generation and maximize energy efficiency to achieve energy balance [7, 8]. A key component of every ZEB project is an energy-efficient building design

[9, 10]. The size and expense of a renewable energy system are lowered when a building's energy efficiency is maximized prior to installation [11]. The design team can evaluate energy-efficiency strategies and model zero-energy systems by using energy simulation tools [12]. The aforementioned approaches comprise design solutions that employ components that mitigate energy consumption, such as highly efficient building envelopes, natural ventilation, daylighting, solar shading, window and glazing selections, passive solar heating, and daylighting [13]. After the building's energy loads are minimized, high-performance systems and equipment, such as highly efficient HVAC (heating, ventilation, and air conditioning) systems, lighting controls, energy-efficient appliances, and high-performance water heaters, can be used to further reduce the remaining loads [14]. Renewable energy systems can provide the residual energy needs once efficiency measures are put in place. Photovoltaics (PV) and solar water heaters are examples of common renewable energy systems [4, 13, 15]. Buildings with minimal energy consumption and costs comparable to conventional buildings can be designed and constructed with the help of energy and environmental design guidelines, protocols, and literature like those cited in [16-20]. Modern, cutting-edge technologies aren't always necessary for ZEBs, though. In actuality, streamlining a building system makes it more likely that the structure will be correctly constructed and operated [17]. Due to its substantial reliance on imported gas and oil, which account for 94% of its energy supply, Jordan is susceptible to price fluctuations. In light of this, the Ministry of Energy and Mineral Resources has revised the master plan for the energy sector for the years 2020-2030. The strategy's lofty goals include achieving a 30% share of renewable energy in all electrical producing capacity and a 14% contribution to the energy mix overall by 2030 [21]. With 330 bright days per year and an annual daily solar irradiation ranging from 5 to 7 kWh/m2, the country also has an abundance of solar energy potential. To encourage the development of renewable energy sources, particularly photovoltaics and onshore wind energy, the nation has put in place a comprehensive framework that includes regulations, regulatory measures, financial incentives, and tax exemptions [22]. With a payback period of fewer than six years, their cost effectiveness makes them a financially appealing option, especially for buildings utilizing more over 5000 kWh yearly [23]. The second-largest energy consumers in Jordan are residential buildings, according to the Ministry of Energy and Mineral Resources [24]. They make up 72% of all the buildings in the nation, and as the population has grown, so too have their numbers. Jordan will need to accommodate about 44,000 extra households per year by 2030, for a projected total of over 352,000 new households. Therefore, residential

structures offer a fantastic chance to achieve significant energy savings. Residential building energy consumption can be lowered by 70% by implementing low-energy usage intensity (EUI) design concepts [25]. For example, the average annual energy usage of Jordan's traditional households-which make up 63% of residential buildings-is 267 kWh/m2 and they do not follow the country's energy code. On the other hand, an average home that meets the national energy requirement uses between 100 and 150 kWh/m2 annually [26]. The current national energy code offers a basis for energy-conscious design, even though the application of energy-efficient techniques in Jordanian residential buildings is still restricted. This is especially true when it comes to technologies like Photovoltaic (PV) systems, daylight systems, and advanced insulation. On the other hand, the lack of well-defined zero-energy standards for the residential market presents a chance to develop zero-energy designs that can work as models and stimulants for environmentally friendly building methods [27]. The residential sector in Jordan is made up of a wide variety of house types, with the majority of them being found in suburban and rural areas (78% of the total). Houses (DAR), apartments, and villas made up 55%, 42%, and 2.4% of the housing distribution in suburban regions, respectively, whereas the distributions in rural areas were 88.9%, 9.9%, and 1.2% [28]. Jordan's climate is characterized by desert conditions and ranges from mild to severely hot. High temperatures are a hallmark of summers, and the winter months see about 75% of the yearly rainfall. Furthermore, dry winds have an influence on the climate of Jordan, which results in notable variations in temperature [29]. It is standard procedure to create plans for appropriate building typologies in order to support ZEBs. Each geographic region's architectural designs must be specific to that region and reflect a dominant building type there [30, 31]. However, statistical research on existing building design characteristics must be done before moving further with these suggestions' zero-energy design. Building energy performance and occupant requirements ought to be the main topics of these investigations. Additionally, statistical building analysis, architectural design, and the following design and selection of various energy-related systems are key approaches to achieve zero-energy design [32]. The understanding of energy efficiency and ZEBs has been aided by a number of studies [33-54]. Zhou [33], for example, looked into how well ZEBs operated, using energy end-use simulations in the design phase and PV system selection thereafter. Additionally, the study contrasted the simulated design-phase results with the real energy usage of ZEBs that were in operation. Deng and Attia [34, 35] made significant contributions to the field by supplying energy-focused instruments and protocols that included meteorological factors, thereby giving invaluable assistance for the assessment and advocacy of ZEBs. In order to create benchmarks and evaluate the energy performance of the first design concepts, engineers used energy modeling tools. Interestingly, the early stages of design were the main target audience for these techniques.

The possibility of enforcing energy conservation criteria to raise the energy efficiency of residential structures in Jordan and Oman was investigated by Albdour and Alalouch [26, 36]. Their results, which showed a savings of up to 48%, were produced using energy simulation software and showed the significant positive impact of implementing these codes on annual energy use. The authors evaluated the consequences of enforcing minimum energy needs in areas with warm, humid temperatures.

Field measurement and evaluation procedures for ZEBs were established by Liu and Danza [37, 38], who concentrated on aspects pertaining to HVAC system energy consumption and indoor environmental quality. The HVAC system used about 33 kWh of energy per square meter on average. Significant drops in cooling and heating loads-up to 55% and 54%, respectively-were the result of this research. They came to the conclusion that NZBs use less energy while offering respectable thermal comfort and good indoor air quality (IAQ). It is crucial to remember that the papers mostly addressed HVAC and IAQ system performance; they did not address other systems like lighting or water heating.

The study undertaken by Hoseinzadeh, Lohwanitchai, Zahedi, Wang, and Hu [39-43] examined buildings that had zero-energy design systems, with an emphasis on the installed systems' economic feasibility. Using both qualitative and quantitative methodologies, energy efficiency and cost studies were carried out with a typical residential building serving as the baseline. The results showed that there was no discernible difference between a ZEB's actual cost and that of a traditional construction.

Zhang, Gao, and Delavar's [44-46] thorough examination of mathematical modeling and control techniques established the foundation for ZEB research. These research investigated the synergy between rule-based and model predictive controllers and building physics and energy technologies in a seamless integration. These studies, which were aimed at researchers, designers, and engineers, created a foundational framework for coherent building modeling and control in the setting of ZEBs.

Okonkwo and Zhu [47-49] provided a thorough analysis of ZEBs and the difficulties in commercializing them. The studies included recommendations for improving current building technologies, with a focus on removing obstacles to their broad implementation. Furthermore, the research produced scenarios for analyzing the energy consumption of buildings, highlighting the importance of implementing almost ZEBs, ZEBs, and ultralow-energy buildings for significant decreases in the total energy consumption of buildings.

A critical evaluation of the definitions of ZEBs that are now in use was carried out by Marszal, Hernandez, and D'Agostino [50-52], who also investigated a number of methods for calculating ZEBs and evaluating their advancement in Europe. The NZEB definitions' discrepancies were also looked at, and the definitions of EU-and US-NZEBs were contrasted. The assessments also covered important topics including the energy efficiency standards, indoor climate, energy metric, balancing period, energy consumption kinds, renewable energy supply alternatives, connectivity to energy infrastructure, and energy efficiency criteria.

Studies by Bataineh and Abu Qadourah [53, 54] concentrated on lowering energy use in homes in Amman, Jordan, which has a warm, dry climate. In addition to using building simulation tools to look into different design elements, passive design measures were also applied. To determine the best course of action for lowering energy consumption, the effects of each intervention on the energy demand of residential structures were evaluated both singly and in combination with other measures. The results showed a large potential for energy savings, with annual usage reductions for heating, cooling, and lighting of 71%, 78%, and 53%, respectively.

Nonetheless, little research has been done on ZEB design. The majority of research [33-54] has concentrated on theories, definitions, methods for evaluation and validation, indoor air quality (IAQ), mathematical models, cost estimates, and thermal comfort. However, prior research has mainly disregarded the comprehensive planning of ZEBs appropriate for various climates and building attributes. The urgent necessity for this current study is highlighted by the lack of standards for zero-energy residential structures and the paucity of studies customized to different climates and building characteristics.

Methodology

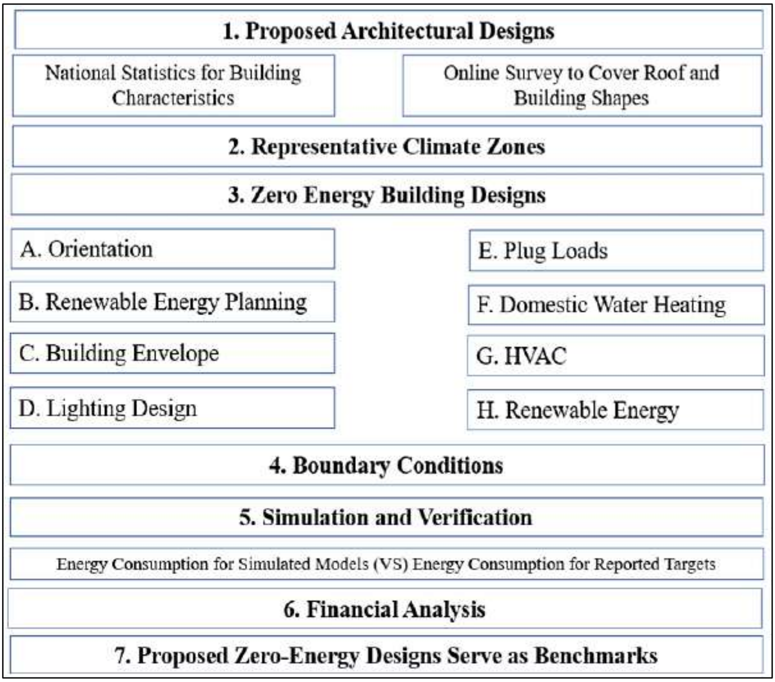

Fig 1: Design process flowchart

Surveys and statistics are useful resources for comprehending the features of buildings [55-58]. The suggested architectural models in this study were designed using information from an online survey and national statistics. Recent statistical data, including building sites, areas, number of floors, ceiling height, color, materials, and building type, were obtained from the Jordanian Department of Statistics (DOS) [59]. The data was analyzed with an emphasis on different design aspects and owner preferences. Design boundaries and architectural methods were established based on insights from earlier studies [30, 60-62]. An online survey was carried out to collect responses from about 2500 homeowners who plan to build a home by 2022, out of an expected 44,000 registered owners in Jordan that year [59]. This information was used to supplement the DOS data.

Over a ten-week period, emails and social media platforms were used to distribute the poll. The intention was to gather information about roof and building shapes-aspects not included in the DOS data. The smallest survey sample size needed to reach a 95% confidence level, a 5% margin of error, and a sample proportion of 0.5 was determined to be 381 respondents. The high participation rate was partly attributed to the survey's simplicity, which concentrated on preferred building forms and roof kinds.

In order to model zero-energy systems and confirm energy end-use, energy simulation tools (IDA ICE, OpenStudio, Revit Daylighting Analysis, and PVWatts) were also utilized, particularly due to budgetary constraints and the restricted options for experimental work in the planned structures [63-65]. Fig. 1 summarizes the conceptual design approach, and the processes that gradually advance the designs toward the zero-energy target are described in detail in the sections that follow.

Proposed Architectural Designs

The homeowners survey and DOS data reveal the prevailing preferences for residential building characteristics. Suburban or rural settings are preferred over infll or confined sites by 78% of respondents. The most common building shape selected (79%), with a sizable majority expressing a preference for structures and areas between 120 and 250 square meters (85%). The most popular sizes were kitchens (15-20 square meters; 57%), and bedrooms (16-20 square meters; 64%). Homes with three to four bedrooms were preferred by the majority (72%), and large roofs (84%), in particular, were preferred. Sixty percent of respondents favoured single-story structures over multi-story ones. Over 98% of respondents said they favoured white for their buildings, while 82% said they preferred using local stones and cement bricks. DAR and Villa were the most popular residential construction configurations, with 73% of them. The design and modeling of four exemplary fat-roofed cubic residential buildings were greatly influenced by the findings. These designs featured two one-story homes with typical sizes between 150 and 200 square meters and 200 and 250 square meters, as well as two two-story homes in comparable area ranges. These designs complement Jordan's prevailing architectural style. These homes often have a floor plan that begins with an entry that leads to the living room and reception area, then continues with a hallway that leads to the bedroom. There are typically two external entrances as well: one next to the kitchen and the other at the main entrance.

Zero-Energy Design

The orientation methods that affect on-site energy output and passive solar design characteristics like sunshine, shading, and thermal mass are more favorable in suburban and rural regions. It has been shown that sun control systems work better on north and south façades. Therefore, the building's east–west axis orientation was chosen to provide the best solar orientation possible across a range of Jordanian climates and architectural styles [68]. With regard to solar gain and glare on the east-and west-facing façades, this orientation minimizes issues. Additionally, this orientation makes the south-facing façade's shading measures more effective. A wise design plan also calls for windows that improve the amount of natural light in a room. By increasing the glazing area on the north and south surfaces relative to the east and west surfaces, this goal was accomplished. It is noteworthy that, as demonstrated in [69], the building's east-west axis can be moved by up to 20° without appreciably altering the overall energy usage. While there are alternative sustainable energy sources, photovoltaic (PV) systems are the most common and can be placed in the majority of buildings. Strategically positioned on large roofs, solar panels-a vital component of PV systems-minimize their environmental impact and guarantee sufficient roof area for the production of renewable energy [70]. Flat roofs were selected because they are suitable for installing PV systems and because property owners have shown a significant preference for them.

Discussion

We created benchmarks for zero-energy residential buildings in Jordan with this study, focusing on cost- and energy-effectiveness in comparison to traditional code-compliant homes. The average EUIs of the suggested designs exceeded those of typical American, Saudi Arabian, and Jordanian homes (one, two, and three climate zones, respectively) over a range of Jordanian climatic zones [26, 54, 92]. The energy requirements for equipment, lighting, heating, cooling and general operation were all in line with the stated goals [89].

The stability of lighting, heating, cooling, and total energy performance are highlighted by minimal differences in the EUIs within the same climate zone, underscoring the significance of the suggested designs in various climatic zones. The highest average energy consumption was recorded in climate zone B1, at 64.4 kWh/m2 year, which was higher than that of climate zones B2 (64 kWh/m2 year) and B3 (60 kWh/m2 year). The reason for this disparity is the harsh weather, which caused an average increase of 4 kWh/m2 in comparison to B3 and 1 kWh/m2 in comparison to B2.

In line with earlier research on lighting in Jordan, the EUI values for equipment and illumination showed considerable uniformity within each climate zone [53, 54]. Warm and arid climate zone 3B stands out as having the highest EUI for heating, averaging 27.5 kWh/m2 year, indicating a significant need for heating energy. In contrast, compared to zone 3B, climate zones 1B and 2B showed comparatively lower heating demands, with EUI values of 17.7 and 17.1 kWh/m2 year, respectively.

Conclusion

Across this work, we created reliable criteria for Jordanian zero-energy residential buildings across a range of climate zones. The primary objective was to create designs that serve as standards, promoting the highest levels of energy efficiency and the use of renewable energy in residential building. The results demonstrated that the suggested designs outperformed normal residences in various nations by a large margin. This emphasizes how effective zero-energy designs are in the various climates around the nation. The incorporation of photovoltaic systems, in particular, is essential to reaching zero-energy objectives. The PV Watts calculator's estimated generation of almost 110% of the anticipated EUI demonstrates the effectiveness of this strategy. The economic feasibility evaluation shows large cost savings in addition to huge energy savings. Furthermore, at least 80% of the total number of inhabitants reported feeling thermally satisfied, indicating that the architecture of the planned homes was extremely important to interior thermal comfort.

The suggested designs' robustness and consistent achievement of energy performance targets across a range of climate zones were demonstrated via validation using the building energy tools Open Studio and IDA ICE. This comprehensive method, which combines climate concerns, energy-efficient technologies, and architectural choices, establishes the groundwork for a workable Jordanian zero-energy design. The purpose of this guidance is to assist designers, builders, and owners in encouraging the construction of energy-efficient and environmentally responsible buildings in similar climates.

This study fills in important gaps in sustainable construction techniques, taking into account Jordan's large energy use in the residential sector and its ambitious energy goal for 2030. The suggested zero-energy designs support the global shift towards ZEBs by acting as guidelines and standards for upcoming building techniques. With possible implications beyond its immediate context, this study offers specific benchmarks, designs, and a comprehensive guide adapted to Jordan's unique construction and climate features. It offers invaluable insights into the field.

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Chapter - 26
Potential for Wind Power in India: A Comprehensive Overview

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Chapter - 26

Potential for Wind Power in India: A Comprehensive Overview

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Abstract

In this paper, various facets of India's wind power potential are reviewed. Overuse of fossil fuels led to serious issues like pollution and global warming as well as environmental deterioration. The supply of fossil fuels is finite and is running out daily. A scenario like this forced people all around the world to come up with creative ways to meet the growing need for energy. The amount of energy consumed determines the economic, industrial, and social development index of any nation. The Indian government has shown remarkable effort in exploring non-conventional energy sources to meet these needs. The Indian government established a distinct ministry to provide the appropriate oversight and operation of the renewable energy industries. The nation rose to the fifth rank in the world thanks to the government's persistent efforts to use renewable energy sources. In terms of installed wind energy capacity, India is now ranked fourth. The Indian government plans to generate 175 GW of electricity from renewable sources by 2022, of which 60 GW will come from wind power.

Keywords: Renewable energy source, wind energy scenario, conventional source, environmental impact

Introduction

Every nation's progress is determined by its energy usage. Countries all over the world are searching for creative solutions as a result of the growing population and the negative environmental effects of over use of conventional energy sources. Researchers, engineers, and scientists from many nations came together to learn how to harness the enormous potential power that nature offers. Ultimately, they discovered that geothermal, hydro, solar, wind, and biogas energy can all be extracted [1]. A few nations concentrated on wind energy, which is derived from the natural environment.

India was likewise adamant about looking into alternative energy sources. The Ministry of New and Renewable Energy (MNRE), a distinct ministry established by the Indian government, is responsible for overseeing and monitoring the use of renewable energy sources and taking appropriate measures for their advancement [2]. In addition to producing sustainable energy, wind energy offers several job opportunities, both locally and internationally. The World Energy Council research [3] states that by 2050, it will be difficult to meet the world's energy needs due to population growth, and that patterns will have completely changed from what they are today. In line with the World Energy Council's definition, energy might be defined as follows: energy security, energy equity, and environmental security. In light of energy sustainability and determining the best way to synchronize these three goals, establish a "trilemma" and gives many nations the foundation for prosperity and competitiveness in order to meet the demands of regulators, governments, stakeholders, social and economic issues, natural resources, and environmental concerns [4]. It provides a clear framework for the many stakeholders to receive dependable energy and sustainable energy transformation. India made impressive strides in addressing environmental issues and the problem of sustainable development. India is committed to increasing the percentage of installed capacity from non-conventional sources of power to 40% by 2030 in accordance with the United Nations Framework Work Convention on Climate Change Improvement [5]. Aiming for 175 GW of renewable energy capacity by 2022, the Indian government has allocated 100 GW to solar power, 60 GW to wind power, 10 GW to biomass/biogas, and 5 GW to small hydro projects dispersed across the nation. The amount of electricity generated by non-conventional sources increased at a compound annual growth rate of 18.2% over the fiscal year 2015-2018. It took only 4.8% of energy production from traditional sources over the same time span to reach this compound annual growth rate. In this study, we give a basic analysis of renewable energy, focusing on wind energy and its availability, achievements to date, current situation, future plan, and activities.

The Current Status of Energy Demand

In recent years, India's output of wind power has substantially increased. As of October 2018, the installed capacity of wind power had climbed to 34977 MW [6]. When it comes to the production of wind power, India comes in fourth place worldwide. India has been primarily separated into three sectors: Central, State, and Private, each belonging to a different zone, based on the installed power capacity. According to data available as of March 31, 2018, there are 344002.39 MW of installed capacity from conventional and renewable energy sources combined. There are 69022.39 MW of installed capacity from renewable sources out of this total. This is 20% of the installed capacity in total [7]. It's interesting to note that almost 50% of the installed capacity of renewable energy comes from wind energy. To find out the installed capacity in both the conventional and non-conventional sectors in India, consult tables 1 and 2. The Indian government's tremendous support and commitment to renewable energy has resulted in a dramatic decline in wind power costs. The cost of wind electricity per unit in 2014 was 4.2(Rs.) [8]. In 2018, its price fell dramatically to 2.43(Rs.) in the absence of any direct or indirect subsidies. To increase openness and lower developer risk, the Indian government has released guidelines for tariff-based wind power auctions. Additionally, it attests to a larger return for investors.

The production of renewable energy is rising extremely quickly. India contributes around 4% of the world's total electricity generation and 4.4% of the world's capacity for renewable energy [9]. According to the International Energy Agency's World Energy Outlook, global development toward renewable energy supply is expected to reach 4550 GW by 2040. In the 2018 fiscal year, India's non-conventional power generation (apart from huge hydro) surpassed 101.84 billion units. India benefits greatly from a varied geographic environment. India's traditional energy resources are finite and rapidly depleting, making it difficult to meet the country's growing energy needs while also supporting a rapidly expanding economy.

However, India has enormous potential for renewable resource-based solar and wind energy. Certain regions of the nation see exceptionally high average wind speeds. The main expansion of wind power resources is in the north, west, and south. With an installed capacity of 8197.08 MW as of September 2018 in the fiscal year 2017-2018, Tamilnadu leads the state in terms of installed wind power capacity [10]. Gujarat, with an installed capacity of 5702.30 MW, comes in second.

The Distribution of Wind Power Potential by State is then explained

A) Tamil Nadu: With 8197.08 MW of installed wind capacity, Tamil Nadu leads all other states in this regard [10]. The Tamil Nadu government recognized the importance of renewable energy and created the Tamil Nadu Energy Development Agency (TEDA), a distinct organization. Denmark is in first place with 53% of the country's net energy demand, ahead of Uruguay and Southern Australia, according to a survey by the Institute for Energy Economics and Financial Analysis (IEEFA) of the USA on the top 15 countries that share solar and wind energy [11]. Tamil Nadu was the only state to make it into the top 10, supplying 14% of its energy demands from renewable sources. Support for the Indian government's ambitious ambition to reach 175 GW by 2022 is positive. Tamil Nadu benefited mostly from abundant wind resources, strong solar radiation, and policies that encouraged investment. The largest wind farm in Tamil Nadu is Muppandal Wind Farm, located near Kanyakumari [12].

B) Gujarat: With 5702.30 MW of installed wind capacity, this state is in second place, behind Tamil Nadu [10]. The average high wind velocity in the Gujarati coastline region of Saurashtra is contributing to the ongoing rise in wind power generation. The Gujarat Urja Vikas Nigam Limited has been able to lessen the strain on load demand for buying power from the open market thanks to an increase in wind power generation [13]. Because wind power costs Rs 3.76 per unit, lowering load demand lessens the financial burden on consumers who purchase energy from outside sources, whose rates are somewhat higher and vary from Rs 4.25 to Rs 4.70 per unit. A 1000 MW offshore wind farm is also being built in Gujarat by the Indian government.

C) Maharashtra: Improved policies implemented by the federal and state governments of Maharashtra have impacted investor interest in installing wind farms, resulting in successful commercialization. The overall installed capacity as of right now is 4784.30 MW [10]. In our nation, there are about 339 confirmed wind sites, with 40 located in the state of Maharashtra [14]. As technology advances, new wind turbines are emerging that take advantage of higher wind densities because of their greater height, less setup costs, and reduced site requirements. The largest wind farm in the state of Maharashtra is Brahmanvel Wind Farm Dhule [12].

D) Karnataka: With a total installed capacity of 4509.45 MW, this state is ranked fourth in India [10]. According to a research from the Institute for Energy Economics and Financial Analysis [15], Karnataka has emerged as the leading state in India in terms of installing renewable energy. According to the report's conclusion, Karnataka benefited from their dependable policy and encouraged the development of new hybrid wind-solar projects. The state produced 5 GW in 2017-18, bringing the total installed capacity of renewable energy to 12.3 GW as of March 2018, according to the study. The largest wind farm in Karnataka is Tuppadahalli, which is situated 260 kilometers away from Bengaluru [12].

India’s Development of Offshore Wind Power

India's coastline spans 7517 km, of which 5423 km are in the peninsula and 2094 km extend to the island chains of Andaman, Nicobar, and Lakshadweep [04]. As part of a strategic effort to ensure long-term energy security, India began extracting offshore wind energy a few years ago. The benefit of capturing offshore potential is that power is available near the load center and wind conditions are expected to be more consistent and less sporadic.

India will receive assistance from the consortium overseen by the Global Wind Energy Council for its offshore wind project. The World Institute of Sustainable Energy (WISE), DNV GL, Gujarat Power Corporation Limited (GPCL), and the Center for Study of Science, Technology, and Policy (CSTEP) are the remaining members of this collaboration. On June 15, 2015, the National Institute of Wind Energy (NIWE) was joined to the collaboration as a knowledge partner [16]. It was founded in response to a project proposal that was requested under the auspices of the Indo-European Cooperation on Renewable Energy Program, and it is supported by a European Union grant. This group, which maintains regular communication with the State governments and the Ministry of New and Renewable Energy (MNRE), declared that the Project will steer the growth of offshore wind power in India and help the country transition to using clean technology in the energy sector. The primary goal of this project was to conduct technical and economic analyses to determine the viability of developing offshore wind power in the states of Gujarat and Tamil Nadu. India took a step closer to putting the offshore wind farm into operation. The National Institute of Wind Energy (NIWE), the government's research and development organization, has expressed interest in working with wind energy companies to commission an offshore wind power plant in Gujarat's Gulf of Khambat that has a capacity of almost 1000 megawatts (MW) [17]. It is important to keep in mind that wind plants are windmills that are placed on the sea floor as opposed to on land. In order to generate enough power, it accommodates larger wind turbines.

March 2018 saw the official announcement to look into the viability of building an offshore wind farm close to Pamban Island off the coast of Tamil Nadu. The fundamental idea behind this is that the combined capability of five or four windmills can produce six megawatts.

Wind Power's Impact on the Environment

Compared to other traditional sources, wind power has less impact on environmental issues. However, there are still some topics that animal and environmental organizations bring up, which sparks debates about wind farms. A quick review of the current situation is necessary to determine the degree to which it is true. Here, some detrimental consequences on the environment are taken into account.

A) **Noise:** Every mechanical system, including turbines, emits noise as they operate. The sound of the wind usually outweighs the sound of the turbine in most turbine cases. Compared to modern wind turbines, older wind turbines make a lot more noise. In comparison to previous models, wind turbines are now quieter due to changes made by engineers in their design. Modern wind turbines are designed with the ability to convert a sizable percentage of wind energy into rotational torque, which reduces noise. Using insulating material and placing it properly can help lower the level of noise.

B) **Visual Impact:** In this instance, the majority of wind farms are situated in open, far-off areas, making them visible from a great distance. This causes aesthetic problems, which in turn ruins the beauty of the natural world. Such a problem can be handled with proper siting. One approach that should be used is using numerous locations, which entails having a small number of wind turbines at one site and other turbines at different locations within the same region [18].

C) **Bird and Bat Mortality:** This is the most contentious problem that many environmental and wildlife organizations have brought up. This topic is mostly driven by the deaths of bats and birds at the wind plant site. Some reports, however, claim that there are only a few bird deaths and that they have little impact on the birds' lives. The significant problem of habitat fragmentation has been brought up in Finland and Norway. They contend that vast forests or grasslands free from human interference are necessary for wild animals to exist, particularly reindeer herders [19]. Nonetheless, studies conducted at Oslo University come to the conclusion that it has little bearing on the husbandry of reindeer. However, there isn't a single report about harmful effects on wildlife in India, thus drawing any conclusions about it is challenging. However, Karnataka has stopped installing wind farms because environmental groups are worried. They were worried that wildlife would be negatively impacted by road building and other associated activities. Environmental organizations further claimed that the study report was completed quickly, a claim that the Environmental Impact Assessment (EIA) committee refuted. Nonetheless, the Court is currently deliberating this issue [19]. To determine the best course of action for reducing environmental concerns, the wind industry in various nations maintain regular communication with the top environmental and wildlife organizations. Numerous nations are encouraging fresh investigations into this problem and disseminating the concept and their experiences globally. Research is being conducted to lessen the effects of many issues, such as electromagnetic interference and pollution of the water and land.

New Developments in Wind Energy

India became a hotspot for investors in the renewable energy sector, which attracted $6.26 billion in foreign direct investment as of December 2017. In the 2017 Renewable Energy Attractive Index, India came in at number two [9]. Since 2014, the Indian renewable energy sector has received direct and indirect investments totalling approximately 42 US$ billion. Frequent auctions with more clarity and openness reduced the tariff in Renewable Energy's various projects. The development of offshore wind farms is permitted up to 12 nautical miles offshore, per the National Offshore Wind Energy Policy of 2015. There are 200 nautical miles of ongoing research and development. Single window clearance has been made available and supported by this policy. There will be a 10-year text holiday for offshore wind energy generation. By creating a structure that facilitates repowering, India has implemented an efficient repowering policy to promote the consistent use of wind power resources. New wind energy projects are eligible for an interest rebate under this scheme, with a 0.25% interest rebate. All fiscal and financial gains will be awarded to the new wind energy project. In order to reach its goal of having 10 GW of wind-solar hybrid capacity by 2022, India has introduced a Wind-Solar Hybrid strategy. Wind projects with a power output of 50 MW or more will be linked to interstate transmission systems, according the Wind Bidding Scheme. 25-year power purchase and sale agreements will be available under this program. By 2022, the Indian solar and wind energy sectors are projected to create over 300,000 jobs [9]. In the last four years, the wind power plant's capacity has expanded by 1.6 times [8]. In 2013 and 2014, the total installed wind power capacity was 21000 MW; as of October 2018, that figure had risen to 34977 MW [6].

Conclusion

Ultimately, it is evident that utilizing wind power has very little impact on the environment and helps to estimate long-term energy security plans while also relieving the need for power generation from conventional sources. India has made great strides in the last several years to construct wind power, ranking fourth in the world, but the nation still needs to fully utilize the wind potential that nature has to offer. In order to draw in investors and guarantee them larger returns, the Indian government introduced a more dependable strategy. However, India must undertake the task of integrating medium-wind electricity produced by various suppliers into the system. In order to motivate individuals to support programs promoting renewable energy, India should also offer financial support to small and medium-sized wind power providers. Promoting cutting-edge technology is necessary to improve wind predictions, site selection, and wind turbine design efficiency to reduce environmental effect.

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