# ShodhDhara

## (OUTR RESEARCH CONCLAVE 2026)

February 27-28, 2026

## ODISHA UNIVERSITY OF TECHNOLOGY AND RESEARCH BHUBANESWAR

## VISION

To be a leading University that fosters knowledge provides transformative education along with the scope for extraordinary research and an enabling environment to create technocrats and innovators equipped to address the challenges of society and industry.

## MISSION

- To create ideators and leaders to develop human resources equipped with creativity, technology and passion for the betterment of humankind by providing an appropriate and conducive ambience.
- To provide an education that transforms students through innovative/ relevant/ appropriate course work and makes them future-ready.
- To address problems faced by the society through nurturing talent and carrying out purposeful research.
- To collaborate with other academic institutes, research organizations and industries across the globe to strengthen the education and research ecosystem.
- To encourage teamwork through the development of harmony, tolerance and co-operation.

## CORE VALUES

The core values adopted by the University as enduring principles are Integrity, Excellence, Accountability, Transparency and Empathy.

- Integrity: Research and teaching shall be carried out in an environment of academic freedom and honesty adhering to the highest standards of ethics in all its activities.
- Excellence: The University is committed to making continuous improvement in all spheres of its activities for the attainment of excellence. The University will recognize exceptional efforts through awards and honours.
- Accountability: The University is a recipient of public funds and acknowledges that it is accountable to the people of the state and to all its stakeholders.
- Transparency: The University will function according to defined procedures and rules, which will be informed to all stakeholders. The University will make public all important information related to its functioning.
- Empathy: An awareness of the conditions of the weaker sections of our society and contributions addressing towards solution of their problems will form an integral part of the research and education programmes of the University.

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**ODISHA UNIVERSITY OF TECHNOLOGY AND RESEARCH**
Techno Campus, Ghatikia, PO: Mahalaxmi Vihar, Bhubaneswar-751029
Odisha, India

## SHODHDHARA (OUTR RESEARCH CONCLAVE 2026)

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**ODISHA UNIVERSITY OF TECHNOLOGY AND RESEARCH**
Techno Campus, Ghatikia, PO: Mahalaxmi Vihar, Bhubaneswar-751029
Odisha, India

**Date: 22.02.2026**

**Prof. Bibhuti Bhusan Biswal**
Vice-Chancellor
Convenor,
OUTR Research Conclave-2026

# *Message*

It gives me immense pleasure to know that Odisha University of Technology and Research (OUTR) is going to hold its second Research Conclave meet on 27-28th February, 2026. This is going to be a historic day as the research scholars, faculty, and students shall be a part of the first of its kind event organized by OUTR.

Research has played a pivotal role in shaping today's society. Research today is not confined to disjoint boxes but demands collaborative contributions from researchers in diverse fields to deliver truly effective solutions to the real-world problems. The explosion of information and dissemination of knowledge to every nook and corner of the world have opened the doors to a multitude of research opportunities in all fields. Breakthroughs and innovations in the field of technology have played a crucial role in transforming altogether today's world as a whole. It is, therefore, essential to keep abreast of a rapidly changing scenario in the developments taking place in various facets of technology and come up with new ideas to envision a better tomorrow for all.

Since its inception as a University in 2021, OUTR is committed to imparting quality education, extensive research, and innovation in technology. The sole objective of this Conclave is to bring all researchers, faculty, and students under one umbrella where they showcase the progress of their novel work, share and discuss ideas, propose innovative solutions to existing problems, and deliberate upon a multitude of topics to provide a common platform for sustainable development.

I earnestly hope that this conclave will prove to be extremely fruitful and useful for all participants, furthering new paradigms of research and ushering in an ambience of growth driven by technological innovations and research.

I wish the conclave a grand success.

**(Prof. Bibhuti Bhusan Biswal)**

**Prof. A. N. Acharya**
Dean, Academic Affairs &
Convenor, OUTR Research Conclave-2026

**ODISHA UNIVERSITY OF TECHNOLOGY AND RESEARCH**
Techno Campus, Ghatikia, PO: Mahalaxmi Vihar, Bhubaneswar-751029
Odisha, India

**Date: 23.02.2026**

# Message

The Odisha University of Technology and Research (OUTR) was established as a Unitary Public University on 8th October 2021 through the Odisha University of Technology and Research Act, 2021 (Odisha Act 17 of 2021), Skill Development and Technical Education Department, Government of Odisha. It may also be mentioned that this University was established by upgrading the College of Engineering and Technology (CET), Bhubaneswar, which was established in 1981. The University, OUTR, started functioning since 8th October, 2022.

The University offers 15 Undergraduate programs and 28 Postgraduate programs in various disciplines of study such as Engineering, Architecture, Planning, Science, and Management for the students of Odisha. At present, 5070 students are pursuing their studies in these programs.

**Dr. APJ Abdul Kalam**, the 11th President of India, an eminent scientist and visionary leader, once said

*"The ignited mind of the youth is the most powerful resource on the earth, above the earth, and under the earth*."

For better exploitation of these powerful resources, the University takes the solemn opportunity to organize a **Research Conclave 2026** for the second time on February 27-28, the day **National Science Day** is celebrated in India every year to mark the discovery of the Raman effect by Indian Physicist Sir C. V. Raman on February 28, 1928.

The objectives of the research conclave are to bring together young, budding researchers, scholars, and students from various academic disciplines to exchange ideas, present their research findings, and explore interdisciplinary research. It will serve as a dynamic platform for the young minds to converge, collaborate, and overcome the challenges using the best opportunities. It has rightly been said that discovery is a journey, not a destination, and that every question answered opens the door to new mysteries. As we embark on this journey of discovery and intellectual exchange, let us keep in mind the impact of our collective efforts. The insights and innovations shared here have the potential to shape not just the future of science and technology, but the future of society as a whole.

On behalf of the University, I congratulate all the participants, particularly students and young researchers, for their enthusiasm to make it a success. In addition, my heartfelt thanks to all the committee members, authorities and staff members of the University for their valuable support to let the dream become a real vibrant event.

**(Prof. A. N. Acharya)**

**ODISHA UNIVERSITY OF TECHNOLOGY AND RESEARCH**
Techno Campus, Ghatikia, PO: Mahalaxmi Vihar, Bhubaneswar-751029
Odisha, India

**Date: 24.02.2026**

**Prof. (Dr.) Aruna Tripathy**
**Professor, School of Electronic Sciences, and Dean, Post Graduate Studies and Research,**

# *Message*

The **Research Conclave-2026** nicknamed "ShodhDhara" is being conducted in **Odisha University of Technology and Research, Bhubaneswar** with an objective to create an open platform for the Research Scholars, Academicians, Researchers, Scientists, persons from industries, R&D organizations and various other stake holders within and outside of the State of Odisha, for promotion of quality research in synchronism with the present days' requirements through exchange of technology and ideas.

I am hopeful that the Research Conclave-2026 will be instrumental in opening various avenues for extending the research outcomes for the benefit of the society as well, through deliberations, poster presentations, invited talks, mutual discussions and interaction.

Tripathy

**(Prof. (Dr.) Aruna Tripathy)**

**ODISHA UNIVERSITY OF TECHNOLOGY AND RESEARCH**
Techno Campus, Ghatikia, PO: Mahalaxmi Vihar, Bhubaneswar-751029
Odisha, India

**Date: 23.02.2026**

**Prof. (Dr.) Ranjan Kumar Jena**
**Professor, School of Electrical Sciences, and**
**Dean, Academic Affair**

# Message

It gives me immense pleasure to present this Special Issue released on the occasion of the ShodhDhara-2026 (University Research Conclave). This publication reflects the vibrant research culture, academic excellence, and innovative spirit that define our university.

Research is the cornerstone of academic growth and societal transformation. The Research Conclave serves as a dynamic platform for scholars, faculty members, researchers, and students to exchange ideas, showcase their work, and foster interdisciplinary collaboration. The contributions featured in this Special Issue demonstrate the depth, diversity, and quality of research being undertaken across various disciplines in our institution.

I sincerely appreciate the dedicated efforts of the editorial team, reviewers, contributors, and organizing committee whose commitment has made this publication possible. Their scholarly rigor and collaborative spirit exemplify the values we strive to uphold.

I am confident that the research findings and insights compiled in this Special Issue will inspire further inquiry, innovation, and meaningful impact. Let this Conclave strengthen our resolve to pursue excellence in research and contribute to knowledge creation for the betterment of society.

I extend my best wishes to all participants for a successful Research Conclave and congratulate all contributors to this Special Issue.

**(Prof. (Dr.) Ranjan Kumar Jena)**

# ShodhDhara-2026 (OUTR Research Conclave)

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# Invited Talk - I

**DR. AMITAVA CHATTERJEE, FNAE**
**PROFESSOR,**
**ELECTRICAL ENGINEERING DEPARTMENT,**
**JADAVPUR UNIVERSITY, KOLKATA, INDIA.**
**URL: https://sites.google.com/site/amitavachatterjee1968/**

**TITLE OF THE TALK:**

## HUMAN-MACHINE INTERACTION IN COLLABORATIVE ROBOTICS

**ABSTRACT:**

Human environment, in which a robot usually operates, is mostly unstructured and dynamic in nature. In such a scenario, robots operating in collaborative modes are gaining more and more prominence compared to robots operating in autonomous mode. For decades, robots in autonomous mode were the preferred solution because it required minimal or no support from humans. But it has been gradually realized that such operations can be too challenging to achieve desired objectives and performances under diverse conditions, and hence, utilization of robots ultimately remain confined to some limited problem domains only. On the other hand, in collaborative robotics, effective human-machine interaction (HMI) can actually significantly help in expanding the horizon and achieving the desired goal under a variety of challenging situations. The recent progression of Industrial Revolution from Industry

4.0 to Industry 5.0 has put the importance of integrating human intelligence and creativity with the capabilities of robots in the front seat. This requires how humans and robots can effectively interact to successfully implement collaborative strategies in conjunction with fundamental modules already present in robots, for example sophisticated sensors and actuators that form the eyes and ears of a robot, the associated control systems, along with state-of-the-art interfacing strategies. New generation of collaborative, intelligent robots rely more and more on machine learning (ML) strategies and development of such ever-evolving learning strategies equip cobots with more meaningful HMI purposes. In fact, one needs to appreciate the fact that it is almost impossible to pre-learn a robot for all types of actions to be performed, in sync with the humans in a practical situation in a dynamic environment. This further necessitates development of more sophisticated learning strategies to cope with those unforeseen scenarios and HMI has a big role to play in it. The Human-machine interaction can take place by employing a variety of gestures from human side which may include hand gestures, eye gestures, voice command based communicative gestures etc., or by showing some visual cues to the robot. Another very important aspect is the maintenance of safety in a common environment involving both humans and robots in operation. The more sophisticated the HMI-based learning strategies are, the more fruitful the utilization of cobots becomes. This simultaneously reduces human workload and increases productivity, whether in industrial automation, manufacturing, or the development of intelligent robotic assistive devices.

This talk will first introduce the importance of HMI and collaborative robotics in the context of current technological developments. Then a detailed discussion will be undertaken on varied aspects of state-of-the-art HMI strategies employed in collaborative robotics using signal processing, computer vision and machine learning algorithms. Particular emphasis will be placed on how gesture- and clue-based guidance can be provided to cobots under challenging ambient conditions and unstructured environments and recent research breakthroughs achieved in that direction will be highlighted.

## BIOGRAPHY – AMITAVA CHATTERJEE

Amitava Chatterjee received the **B.E.E, M.E.E**, and **Ph.D.** degrees in **Electrical Engineering** from **Jadavpur University**, Kolkata, India, in 1991, 1994 and 2002, respectively. In 1997, he joined the **Department of Electrical Engineering, Jadavpur University**, as a faculty where he is currently serving as a Professor. He is a recipient of the **Japanese Government (Monbukagakusho) Scholarship** in 2003 and a recipient of the **Japan Society for the Promotion of Science (JSPS) Post-Doctoral Fellowship** in 2004. In 2004 and 2009 he visited **University of Paris XII, Val de Marne, France**, and in 2017 he visited **University of Paris Est**, as an **Invited Teacher**. Dr. Chatterjee became a **Fellow** of **Indian National Academy of Engineering (FNAE)** in 2018. He is a **Fellow** of **IETE (India)**, a **Fellow** of the **Institution of Engineers (India)**, a **Senior Member** of the **IEEE (USA)**, and a **Life Member** of **Operational Research Society of India**. Dr. Chatterjee's key research interests include *systems and control, signal and image processing*, *AI and ML, intelligent instrumentation, and robotics*.

Dr. Chatterjee has co-authored two books and co-edited two books, all published by **Springer Publishers**. He presently serves/has served in the past as an ***Associate Editor-in-Chief*** of ***IEEE Transactions on***

***Instrumentation and Measurement*,** an ***Editor*** of ***IEEE Transactions on Vehicular Technology*** and ***Engineering Applications of Artificial Intelligence*** *Journal* (Elsevier), an ***Associate Editor*** of ***IEEE Sensors Journal***, ***IEEE Open Journal of Instrumentation and Measurement, ISA Transactions*** *Journal* (Elsevier), and ***Control Engineering Practice*** *Journal* (Elsevier), and ***Artificial Life and Robotics*** Journal (Springer). He has authored/coauthored more than 210 technical articles, including 126 international journal papers. This includes **47 papers in IEEE Transactions/Journals/Letters/Magazines** and **49 papers in Elsevier Journals**. Dr. Chatterjee is recognized in World Ranking of **Top 2%** Scientists from India in the Field of "**Artificial Intelligence and Image Processing**" published by scientists from Stanford University in **2020, 2021, 2022,** and **2023** (both in Life-Long Career category and in Single-Year category, in each year) and in **2024** and **2025** (in Life-Long Career category). He has also served as a ***Jury Member*** of *IEEE Transactions on Instrumentation and Measurement's* ***Best Paper Award Committee*** four times, was adjudged an *Outstanding Associate Editor of IEEE Transactions on Instrumentation and Measurement* five times, a *Top Editor of IEEE Transactions on Vehicular Technology* three times, and an *Outstanding Associate Editor of IEEE Open Journal of Instrumentation and Measurement* three times.

# Invited Talk - II

## Driving Sustainable Mobility: EVs, Microgrids, and AI-Enabled Cyber-Physical Systems

**Professor Bidyadhar Subudhi**
*Director, NIT Warangal*
*Professor, School of Electrical Sciences, IIT Goa*

Sustainable mobility has emerged as a defining technological and societal challenge of the 21st century, with far-reaching implications for energy systems, infrastructure resilience, and climate commitments. While the rapid adoption of electric vehicles (EVs) is central to decarbonizing transportation, large-scale electrified mobility fundamentally reshapes the dynamics of power grids and urban energy ecosystems. High-power, spatially distributed, and time-varying EV charging introduces tightly coupled interactions among renewable generation, power electronics, communication networks, and control layers—posing challenges that conventional, centralized grid and mobility paradigms are ill-equipped to address.

This talk presents a systems-level perspective on sustainable mobility through the lens of AI-enabled cyber-physical systems (CPS). EVs are re-envisioned not merely as transportation devices, but as flexible, distributed energy resources capable of intelligent interaction with local power systems. Renewable-integrated microgrids are highlighted as critical enablers for resilient, scalable, and renewable-powered charging infrastructure across campuses, urban clusters, and transportation corridors. Artificial intelligence plays a unifying role by enabling forecasting, optimization, adaptive control, and secure coordination across multiple spatial and temporal scales.

The talk discusses key scientific and engineering challenges associated with high-penetration EV integration, including multi-time-scale control, distributed optimization, grid stability, cyber-physical security, battery health management, and fast-charging infrastructure design. Emerging trends such as bidirectional charging (V2G/V2H), wide-bandgap power electronics, AI-driven diagnostics, digital twins, and high-power-density converter architectures are examined as foundational technologies for next-generation mobility systems. Selected research contributions—including advanced bidirectional converter topologies, wide-voltage fast-charging architectures, and PV-integrated smart charging frameworks—illustrate pathways toward efficient, intelligent, and grid-compatible EV charging solutions.

The talk concludes with a forward-looking vision emphasizing the role of interdisciplinary research, indigenous innovation, and science-led engineering in realizing intelligent, resilient, and sustainable mobility–energy ecosystems aligned with India's long-term development goals.

The future of sustainable mobility lies in transforming EVs from passive electrical loads into active cyber-physical agents within AI-coordinated, microgrid-based energy systems.

# CONTENTS

# OP-1: Experimental and Computational Evaluation of Hypoxia and Hemolysis Contributions to Erythrocyte ATP Release

**Satabdi Mishra and Ranjan Kumar Pradhan***

*Department of Biotechnology and School of Electrical Sciences, Odisha University of Technology and Research, Bhubaneswar - 751029, Odisha, India*

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**Introduction:** Erythrocyte plays a fundamental role in local control of tissue blood flow in exercise and disease by releasing ATP via dedicated pathways to induce nitric oxide-mediated vasodilation in the vasculature. The hypothesis that erythrocyte acts as an oxygen sensor to release of ATP in regulated manner during hypoxia and associated cellular deformation has sparked much interest in understanding its actual mechanism. However, experiments designed to study erythrocyte ATP release has shown confounding results due to inherent haemolysis (i.e., breaking down of erythrocyte membrane) during experimental procedures *in vitro,* and circulation through capillaries *in vivo*. Therefore, accurate determination and control of experimental hemolysis, and the factors affecting ATP release are important to study the mechanisms of erythrocyte-mediated vascular control in exercise.

**Materials and Methods:** To identify the experimental factors that can be controlled to limit cell lysis during ATP measurement, here we have experimentally and computationally evaluated erythrocyte membrane stability under mechanical, hypotonic, hypertonic and hypoxic shocks based on free haemoglobin and ATP measurements in isolated erythrocytes from whole blood. Erythrocyte membrane fragility was assessed across graded sodium chloride concentrations under normoxic and hypoxic conditions. Free haemoglobin (Hb) was measured spectrophotometrically, and changes in erythrocyte shapes were monitored using compound microscopy to manually and automatically detect hemolysis. Extracellular ATP levels were measured in a luminometer at each ionic condition to assess effect of membrane deformation, hypoxia and hypertonicity. To minimise error due to haemocytometer-based cell counting and hemolysis, a combined Hb absorbance and smear image-based quantification method was developed using image processing and machine learning techniques. A detergent-based calibration reference was incorporated to define complete membrane rupture and normalize haemolytic responses.

**Results:** Decreasing sodium chloride concentration caused a progressive increase in hemolysis under both normoxic and hypoxic conditions. Extracellular ATP increased only alongside measurable hemolysis, indicating that ATP release was primarily due to membrane rupture. Image analysis showed a corresponding decline in intact cell count with increased ghost cells and loss of normal morphology. Factors like centrifugation speed, incubation time and pH of the medium were shown to influence supernatant [ATP], when erythrocytes were exposed to varying oxygen partial pressure in hypoxic chamber.

**Conclusion:** This study demonstrates the quantitative relationships between experimental hemolysis due to centrifugation, osmotic fragility, sample handling and hypoxia-induced ATP release in erythrocytes. Microscopic imaging combined with watershed-based segmentation method was shown to provide a fast and accurate method for quantitative analysis of erythrocyte abnormalities in diseases. Concurrently, the proposed integrative approach provides a framework to study complex interactions between oxygen-dependent membrane stability and ATP release in erythrocytes, highlighting the significance of hemolysis and deformation in ATP hypothesis of blood flow control in health and disease. This work can be further extended to study the role of erythrocyte ATP release in Diabetes, Sickle Cell Anaemia and other cardiovascular diseases.

***Keywords: Erythrocyte; Hemolysis; ATP Release; Image Segmentation; Haemoglobin Absorbance.***

# PP-2: Fabrication and Characterization of Bio-Nanocomposite Films Using Food Processing Waste

**Anyesha Roy Choudhury[1], Sukanya Sahu, Supriya Dash***

*Department of Biotechnology, Odisha University of Technology and Research, Bhubaneswar-751003, Odisha, India*

*Corresponding author E-mail: anyesharoychoudhury@gmail.com, dashsupriya@gmail.com*

**Introduction**: The widespread use of non-biodegradable petroleum-based plastics in food packaging causes serious environmental pollution and ecological imbalance. This has increased the demand for biodegradable and eco-friendly alternatives. Bio-nanocomposite films, developed by incorporating nanoscale fillers into natural polymer matrices, exhibit improved mechanical strength, barrier properties, and functional performance. Due to their biodegradability and biocompatibility, bio-nanocomposite materials are promising for sustainable food packaging. Chitosan from fish scales offers excellent film-forming and antibacterial properties but is brittle and moisture-sensitive. To improve its performance, orange and pomegranate peel powders, rice starch, ZnO nanoparticles, and glycerol were incorporated to develop multifunctional bio-nanocomposite films for intelligent food packaging applications.

**Materials and Methods:** Bio-nanocomposite films were fabricated using the solvent casting method. A 2% (w/v) chitosan solution was prepared in 1% acetic acid, and 50%rice starch(Type3a) extracted from rice water Orange and pomegranate peels were dried, powdered, and added as functional fillers. ZnO nanoparticles were synthesized using the precipitation method with zinc acetate and sodium hydroxide.Various formulations of chitosan, rice starch, ZnO nanoparticles, orange peel powder, and pomegranate peel powder were blended with glycerol, cast into films, and dried under ambient conditions. The films were evaluated for thickness, water solubility, hot water resistance, biodegradability, antimicrobial activity, UV–visible barrier properties, FTIR, colour characteristics, and pH-sensing behavior.

**Results and Discussion:** The films showed smooth surfaces with composition-dependent colour changes, where fruit peel powders imparted natural yellow–brown hues and ZnO nanoparticles enhanced opacity and UV blocking. Film thickness increased from 0.542 to 0.816 mm, while water and hot-water solubility decreased due to improved intermolecular interactions. All films were biodegradable and exhibited strong antibacterial activity against *Escherichia coli* and *Micrococcus lysodeikticus*, especially with ZnO nanoparticles and pomegranate peel powder. UV–Visible and FTIR analyses confirmed ZnO nanoparticle formation and effective component interactions, while pomegranate peel extract displayed pH-responsive colour changes for intelligent food spoilage indication.

**Conclusion**: This study demonstrates the successful fabrication of eco-friendly bio-nanocomposite films from food processing waste and biopolymers, showing enhanced mechanical strength, UV barrier, antimicrobial activity, biodegradability, and pH-sensing properties.The developed films show strong potential as sustainable, intelligent, and active food packaging materials, offering an effective alternative to conventional plastic packaging while promoting waste valorization and environmental sustainability.

**Keywords:** ***Bio-nanocomposite films, Chitosan, ZnO nanoparticles, Food waste, Intelligent packaging, Biodegradable materials***

# PP-3: Valorization of Indian Major Carp Viscera for Fish Protein Hydrolysate Production: A Sustainable Approach to Aquatic By-Product Utilization

**[1]Divyagni Divyajyoti*, [1]Supriya Dash**

*[1]Department of Biotechnology, Odisha University of Technology and Research, Bhubaneswar 751029, Odisha, India*

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**Introduction:** The global fishing industry generates significant waste, with up to 70% of the total catch—including viscera, heads and skins—often discarded or converted into low-value products like animal feed. Fish viscera, which comprise 12–18% of the fish's body weight, are rich in proteins, lipids and bioactive compounds, rendering them a viable source for nutraceuticals and pharmaceuticals. This study focuses on valorizing the viscera of *Labeo rohita*, a freshwater carp widely consumed in India, into Fish Protein Hydrolysate (FPH). While hydrolysis can be performed using acid, alkali or enzymes, the methods differ significantly in outcome. Although acid and alkali hydrolysis are economical, they degrade essential amino acids and reduce nutritional quality. In contrast, enzymatic hydrolysis is preferred for producing high-quality FPH with superior solubility, digestibility and bioactive properties, including antioxidant and antimicrobial activities. Therefore, this research compares the efficiency of chemical hydrolysis (acid, alkali) against enzymatic hydrolysis (using papain and trypsin) to develop functional food ingredients from *Labeo rohita* viscera.

**Methods and Material:** Fresh *Labeo rohita* viscera were washed, homogenized and thermally treated at 95°C for 5 minutes to inactivate endogenous enzymes. The homogenate was subsequently partitioned for comparative hydrolysis. Chemical digestion involved acid hydrolysis (6 M HCl at 118°C for 18 hours) and alkali hydrolysis (NaOH at pH 12.5, 95°C). Enzymatic hydrolysis was conducted using Papain (pH 6.5, 54°C) and Trypsin (pH 8.0, 37°C), with both reactions incubated for 60 minutes under constant agitation. Following hydrolysis, mixtures were centrifuged at 5000 × g for 30 minutes to recover the supernatant. Soluble protein concentration was quantified via the Lowry method (absorbance at 660 nm) using bovine serum albumin (BSA) as the standard, while peptide molecular weight distribution was characterized using SDS-PAGE.

**Result and Discussion:** This study produced Fish Protein Hydrolysate (FPH) from *Labeo rohita* viscera using enzymatic and chemical protocols. Enzymatic hydrolysis with papain yielded 2035ìg/mL of protein, significantly outperforming trypsin (1600ìg/mL) while maintaining peptide integrity. Conversely, chemical methods achieved much higher bulk recovery (alkali: 7668ìg/mL; acid: 7357ìg/mL) but compromised quality by degrading essential amino acids and risking toxic lysinoalanine formation. Consequently, despite the lower mass yield, enzymatic hydrolysis is identified as the superior method for producing high-quality, bioactive peptides suitable for food applications. The gel electrophoretic study showed that FPH contained peptides in the range of d"10–25 kDa. Essential quality of a dietary protein has been recommended to have abundance of peptides of low molecular weights with minimum of free amino acids.

**Conclusion:** This study successfully valorized *Labeo rohita* viscera into Fish Protein Hydrolysate. Although chemical methods offered higher bulk yields, they compromised nutritional safety. In contrast, enzymatic hydrolysis using papain emerged as the superior protocol, yielding high-quality, bioactive peptides (10–25 kDa). This confirms papain-mediated hydrolysis as the optimal method for sustainable functional food production.

**Keywords:** ***Labeo rohita, fish protein hydrolysate, acid, alkaline, enzymatic hydrolysis, papain, trypsin, protein recovery, bioactive peptides, waste valorization.***

# PP-4: Polymorphism: A greener way to tune the physicochemical properties of material

**P Satabdi Patra,[1] Lopamudra Giri[*], Bijnyan Ranjan Das[*], Achyuta N Acharya[*]**

*Department of Chemistry, School of Basic Sciences and Humanities, Odisha University of Technology and Research, Bhubaneswar-751029, Odisha, India*

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**Introduction:** Polymorphism refers to a substance's ability to exist in several crystalline forms. This provides an intriguing, greener and ecologically benign way of tweaking the physicochemical features of materials. In this work, 4-bromophenyl boronic acid (BPBA) has been considered, which is essential for chemical transformations and plays an important role in bioorganic and pharmaceutical chemistry, but its poor water solubility is a major consideration for its handling and application in chemical reactions. The physicochemical characteristics of these polymorphs were investigated which avowed that the newly obtained Form II showed an enhance solubility as compared to its parent form.

**Methods and Material:** All the chemicals have been purchased from Sigma-Aldrich with >99% purity and were used without additional purification.

A mixture of ethyl acetate (10 mL) and dichloromethane (DCM, 10 mL) was charged into a 100 mL round-bottom flask. 4-Bromophenylboronic acid (1 mmol) was added to the solvent system, and the resulting suspension was stirred vigorously. The mixture was heated to reflux at 60 °C and maintained for 4 hours until a homogenous, clear solution was obtained. After heating the hot solution was filtered to remove any insoluble impurities and allowed to undergo slow evaporation at room temperature. After three days, colourless crystals suitable for analysis were isolated. The crystalline material was subsequently characterized through Powder X-ray Diffraction (PXRD) and Single-Crystal X-ray Diffraction (SCXRD) to confirm its phase purity and molecular structure.

**Result and Discussion:** The characterization of 4-bromophenyl boronic acid (BPBA) successfully identified two distinct polymorphic forms, Form I and Form II. PXRD analysis confirmed unique molecular arrangements and both the forms displayed unique characteristic peaks. SCXRD revealed Form I adopts a sheet structure (Triclinic), whereas Form II forms a grid network (Monoclinic). Thermal analysis via DSC demonstrated distinct melting points (285.59! for Form I; 326.28! for Form II) with no phase transitions before melting. Hirshfeld surface analysis further quantified the differences in intermolecular hydrogen bonding strengths between the two forms.

**Conclusion:** In summary, polymorphic forms of BPBA were discovered for the first time. Despite the significant differences in their three-dimensional configurations, strong O-H···O hydrogen bonds stabilized the structure in both cases. Form I create grid networks, while Form II adopt a sheet structure. Furthermore, the physicochemical characteristics of these polymorphs were investigated which avowed that the newly obtained Form II showed an enhance solubility as compared to its parent form. As a result, we believe that the new discovery has given a more environmentally friendly and cost-effective solution to the toxicological issues connected with BPBA.

**Keyword:** ***Polymorphism, Solubility enhancement, 4-Bromophenyl boronic acid, Green Chemistry, Non- covalent interactions***

# PP-5: Production of Sustainable Bioplastic from Coconut Husk: A Green Approach to Convert Agricultural Waste into Eco-Friendly Materials

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**Introduction:** The extensive use of petroleum-based plastics has resulted in ongoing ecological degradation. Main cause being their non-biodegradable nature. This has escalated the search for sustainable and biodegradable alternatives. Bioplastics production from the renewable sources are considered feasible and useful solution. Coconut husk, which people generally discard as waste material, is an abundant agricultural byproduct, which has significant quantity of cellulose, which serves as a natural polymer and a sustainable material for the bioplastic production. Utilizing the coconut husk helps in reducing agricultural waste and also contributes for the production of sustainable and eco-friendly materials.

**Methods and Material:** Coconut husk was cut into 1-2cm pieces, thoroughly washed with distilled water, and rinsed with 50:50 isopropyl alcohol-water mixture before oven drying at 60ºc for 24 hours. Chemical treatment was done following the method developed by Salgado-Delgado *et al.* (2010), with little modification. The fibers were mercerized using a solution containing 40% NaOH, distilled water and methanol for 4-6 hours, (This was done by taking reference from Morales *et al*. (2001), followed by neutralization with 1N HCl, washing and drying. Hemicellulose and surface impurities are removed using 17.5% NaOH and hydrolysis (Moran *et al*.) was carried out using 60% sulfuric acid at 45ºc for 30 minutes. Further bleaching with sodium hypochlorite and glacial acetic acid enhanced fiber purity. The dried fibers were ground into fine powder(cellulose). Starch(3g), glycerol(1.5ml) and cellulose (0.05g) were mixed at 45ºc and 60ºc (continuous agitation) following the (Mali *et al*. (2002) method) and oven dried to form the biodegradable bioplastic film.

**Result and Discussion:** The above concentrations and the starch-cellulose mixture formed a bioplastic film successfully, showing that the processing conditions were appropriate for the film preparation. Continuous heating and stirring helped achieve good mixing of components, while glycerol aided to the flexibility of the biofilm. Hence, the method proved to be a simple yet effective way to prepare biodegradable bioplastic film using the starch and cellulose – based materials.

The biofilm showed less engorgement property, water resistance, they don't easily absorb much water and hence can be considered suitable for the food packaging. The biofilm also showed antimicrobial activity. The biodegradability test of the biofilm was performed by the soil burial technique and was regularly monitored, the results showed gradual increase in degradation especially after 5 days.

**Conclusion:** This study confirms that coconut husk can be effectively utilized as a renewable source of cellulose for biodegradable bioplastic production. The applied chemical treatments successfully enhanced fiber purity, enabling the formation of uniform and flexible starch–cellulose composite films. The results demonstrate the technical feasibility of converting agricultural waste into eco-friendly polymer materials, supporting sustainable waste management.

**Keywords:** Mercerization, hydrolysis, plasticizer, fiber purification, engorgement.

# PP-6: Computational Analysis of the Kinetics and Regulation of Hexokinase in Human Red Blood Cells

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**Introduction:** Hexokinase is the regulator enzyme that catalyses the conversion of glucose to glucose-6-phosphate during glycolysis. The process is the rate-controlling step in glycolysis. As erythrocytes lack the organelle mitochondria, they depend on glycolysis as the sole mechanism for energy production. The described activity of the enzyme has been correlated with haematological disorders, including haemolytic anaemia, as well as metabolic syndromes such as diabetes mellitus. Although several *in vitro* studies have shown the kinetics of hexokinase using commercial enzymes and purified enzymes, the reported kinetic parameters widely vary from study to study. While the conventional kinetic approaches and crystallographic data offer a qualitative picture of how this enzyme works, in isolation, it is unclear how the enzyme contribute to the control of glycolysis in intact system and disease state. In addition, there is inadequate consideration of the enzyme's multi-substrate characteristics and thermodynamics of reaction kinetics in earlier studies. Thus, there is a need of systematic analysis of existing data on substrate-velocity curves, before we asks what is the role of hexokinase in controlling metabolic functions of erythrocytes in health and diseases.

**Materials and Methods:** The present work used a computational approach to systematically investigate the extent to which the reported dissociation constants of substrates may vary among existing kinetic data on human erythrocytes, reported under diverse conditions. Simple Michaelis-Menten kinetic model was used to compare the inconsistencies in the reported velocity curves at a given substrate level, measured under a wide variety of experimental conditions. The existing data were analysed by fitting the model using both Lineweaver-Burk plot and hyparabolic kinetics, and factors affecting initial velocity were identified for further corroboration with *in vivo* kinetics. The model-free analysis of the enzyme were used to design suitable kinetic experiments that may help building more detailed models of hexokinase kinetics.

**Results:** The results of this analysis showed considerable variation in the values of the kinetic parameters associated with the binding of substrates, which indicated problems in identifying true dissociation constants of hexokinase from any single study. Variability in $K_m$ and $V_{max}$ values points towards additional factors playing an essential role in the catalytic activity of the enzyme, and factors other than the binding of the substrate to hexokinase can be determined with additional data on hexokinase activity, measured under physiological and pathological conditions (pH, Temperature). This preliminary analysis suggests, the mechanisms of hexokinase kinetics and regulation in isolated erythrocytes can be better understood using a detailed thermodynamically balanced mathematical model, validated by the hyperbolic relationships of initial velocity and substrate concentrations affective enzymes activity.

**Conclusion:** The current computational analysis of the reported hexokinase kinetic data demonstrates how Linear-Burk plot may introduce serious ambiguity in studying complex enzyme kinetics in vitro and estimating substrate affinities. Future work aimed at isolating, purifying and characterizing enzymes from red blood cells and conduct in vitro kinetic assays to measure substrate –velocity relations for model building to provide better insights into the mechanisms of hexokinase regulation in disease.

***Keyword:*** *Hexokinase, Enzyme kinetics, Erythrocyte, Michaelis-Menten Kinetics, Catalytic mechanism*

# PP-7: Computational Fluid Dynamic Modeling of Flow-mediated ATP Transport in Coronary Vascular Networks

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**Introduction:** Coronary blood flow is mainly governed by numerous determinants including vascular network anatomy, nonlinear blood rheology, local metabolites, ATP released from circulating erythrocytes, and the mechanical interaction of vasculature with heart tissue throughout the cardiac cycle. The range of spatial scales and multi-physics nature of coronary blood flow highlights the need for a computational fluid dynamics (CFD) modeling, which is basically thought to capture accurate distribution of coronary pressure and flow. Recently, medical imaging data such as coronary angiography are combined with 3D computational modeling to predict distribution of various stimuli and intrinsic factors that determine perfusion and shear distribution in right and left arteries. However, building 3D anatomical models of coronary vascular networks has been challenging due to its complex branching pattern, sophisticated geometries (high curvature, bifurcation, and trifurcation) and involvement of multiple local signals that affect vessel resistance to flow. Although the importance of red blood cell ATP release and its effects on endothelium-mediated vasodilation have been experimentally studied using isolated vessel preparations, the ATP-mediated changes in local and global coronary hemodynamic are poorly understood, both in healthy and disease. Therefore, in this study, we have numerically analyzed the effects of vessel geometry and non-linear blood viscosity on regional distribution ATP affecting right and keft coronary hemodynamics.

**Materials and Methods:** Here we have developed 3D network models of left and right coronary arteries to evaluate the impacts of Newtonian and non-Newtonian blood rheology and branching patterns on coronary flow and ATP distributions in left and right coronary arterial trees. Non-steady CFD simulations were carried out with different rheological and geometrical parameters: (i) Newtonian fluid assumption (ii) Non-Newtonian (shear thinning) assumptions, and (iii) effect of bifurcation or trifurcation on hemodynamic indices. Three major hemodynamic indices, wall shear stress (WSS), Oscillatory shear Index (OSI) and relative resident time (RRT) were calculated to compare in right and left dominant control factors. It was found that the relatively lower WSS regions at the curvature and bifurcation or trifurcation sites match with low-shear and low ATP depositions in coronary trees. Moreover, the average WSS and longitudinal pressure gradient are significantly increased with the more complex geometries.

**Results and Discussion**: CFD simulation of blood flow in left and right coronary arterial trees are consistent with in vivo observations, indicating shear-induced ATP released from RBCs are deposited in localized regions of disturbed flow and are likely initiate plaque formation in such vascular territories. Various parametric studies are performed by varying baseline parameters to study their effects on ATP concentrations and spatial distributions.

**Conclusion**: The present 3D networks models of left and right coronary trees shows significant variation in flow-induced ATP release regardless of anatomical variations in both arterial trees. Overall, this computational analysis provides important insights about the possible interaction between left and right coronary vasoregulatory mechanisms, and its impact on regional distribution of flow in the beating heart, and the need for patient-specific modeling of coronary circulation in health and diseases.

***Keywords:*** *Computational Fluid Dynamics, Coronary Artery, Non-Newtonian Blood Rheology, Patient-specific Modelling, COMSOL.*

# PP-8: Exploring the Significance of Biomarker Genes of Coronary Artery Disease using Integrative Bioinformatics Analysis

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**Introduction:** Coronary Artery Disease (CAD) remains a leading cause of global morbidity, yet its underlying genetic mechanisms and specific peripheral biomarker genes are not fully identified. Traditional analysis of gene expression microarray data faces challenges in identifying consistent diagnostic signatures across diverse datasets. This study introduces an exploratory data mining approach to combine micro array gene expression data with pathways information and gene ontology to identify key biomarker genes, the significance of differentially expressed genes (DEGs) and their associated pathways. By leveraging advanced bioinformatics tools, this study aims to move beyond static data observation towards a systematic interpretation of the molecular drivers of CAD progression.

**Materials and Methods:** The study utilized four microarray datasets from the NCBI GEO database (including GSE12288, GSE20680, and GSE23561), focusing on peripheral blood gene expression profiling. Data were taken for rigorous preprocessing, including Log2 transformation and Z-score normalization, to reduce skewness and eliminate technical variance. Principal Component Analysis (PCA) was employed to reduce high-dimensional data and visualize clustering patterns. Weighted Gene Co-expression Network Analysis (WGCNA) was used to identify clusters (modules) of highly correlated genes from high-throughput data (microarray), relating them to clinical phenotypes. After quality assessment, these datasets were selected for in-depth DEG identification using fold change and adjusted p-values. Functional significance was evaluated through Gene enrichment analysis, pathway analysis and the construction of protein-protein interaction networks to map the physical and functional associations of identified proteins.

**Results and Discussion**: PCA and WGCNA results revealed that genes predominantly clustered along PC1, suggesting a shared biological variance or a common underlying mechanism driving expression changes in CAD. The framework successfully visualized gene expression dynamics through Volcano plots and MA plots, identifying significant alterations in molecular functions and cellular processes. The PPI network analysis of 100 top DEGs from datasets GSE12288 and GSE23561 revealed approximately 335 interactions, highlighting the complexity of signaling cascades in CAD. While initial attempts failed to find DEGs with $p < 0.05$ in some datasets, the study emphasizes that results are highly sensitive to normalization techniques and data formats. These findings suggest that an integrated approach combining PCA, functional enrichment, and network topology is essential for uncovering biomarker significance.

**Conclusion:** This study demonstrates the effectiveness of an integrated bioinformatics approach in analyzing the genetic basis of CAD. By standardizing preprocessing and employing multi-layered bioinformatics analysis, the study clarifies the relationship between specific DEGs and their related biological processes. While PCA and WGCNA are invaluable for dimensionality reduction and cluster identification, functional significance of biomarkers relies heavily on refined normalization and the quality of metadata annotation. This study also provides a foundation for future work to integrate additional data of biomarker genes to define novel therapeutic targets for specific cardiovascular disease.

**Keywords:** *Differentially Expressed Genes, Coronary Artery Disease, Microarray Data, Principal Component Analysis, Weighted Gene Co-expression Network Analysis*

# PP-9: Understanding the Molecular Mechanism of Hb-Transition and Allostery: Insights from Salt Bridge Analysis

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**Introduction:** Hemoglobin (Hb) is an important protein responsible for the transport of oxygen in red blood cells, and consists of two alpha and two beta subunits forming a tetrameric protein. A salt bridge, one of the typical structural factors established by non-covalent interactions and plays a crucial role in stabilizing the structure and regulating the physiological function of Hb. However, its role in R-T transition dynamics remains unclear. The transition between the two states of Hb is thought to be mediated by salt bridge formation, structure, breakage of salt bridges between oppositely charged amino acid side chains, and interaction between cytosolic membrane protein Band 3. Although salt bridges are important in maintaining the stability of the T-state and reducing the binding affinity of the protein for oxygen, the role of the salt bridges in the transition to the R-state are yet to be defined.

**Materials and Methods:** In the study, we have used static structural data on high-resolution x-ray crystallographic structures of human haemoglobin, obtained from the RCSB Protein Data Bank to analyse the changes in salt bridge formation or abolition among several deOxy-Hb and Oxy-Hb protiens, measured in diverse studies. The structures of R-state and T-state models of human hemoglobin were obtained based on specific criteria, including the quality of resolution, completeness of á, â, subunits, and minimum mutations. The structures were then systematically analysed using molecular visualization tool PyMOL to identify length and existence of salt bridges. Salt bridges were identified based on the observed interaction between positively charged amino acids, including Lys, Arg, and His, and negatively charged amino acids, including Asp and Glu, with a distance of d”4.0 Å. A comparative analysis was done to identify salt bridges that are specific to the T-state, R-state, or conserved, with special focus on inter-subunit salt bridges.

**Results and Discussion:** Comparative analysis of available high-resolution hemoglobin structures from RCSB Protein Data Bank reveals significant changes in salt bridges depending the oxygenation state of the protein. The interaction shows the changes in salt bridges are due to oxygenation-deoxygenation state transition, consistent with experiments. The molecular visualisation was done using PyMOL tools to identify specific types of interaction, specifically to classify the identified salt bridges as T-state specific or R-state specific or conserved.

**Conclusion:** This study has shown the significance of the dynamics of the salt bridge in the allosteric regulation of hemoglobin and its allostory. This transition of the T to the R state is associated with the disruption and formation of electrostatic interactions. The current results support the notion that salt bridges form the “structural switches” in hemoglobin, holding the T-state together until oxygen binding provides enough energy to break them, enabling the high-affinity R-state.

***Keywords**: Hemoglobin Allostery, R–T Conformational Transition, Salt Bridges, Oxygen Affinity*

# PP-10: Process Validation and Characterization of Biopolymer Chitosan from Aquatic By-products

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**Introduction:** The extraction and characterization of chitosan from freshwater fish and prawn scales have attracted significant interest due to the growing demand for sustainable and eco-friendly biomaterials. Chitosan is a natural polysaccharide obtained by the deacetylation of chitin, which is abundantly present in the scales and exoskeletons of freshwater fish and prawns. Fish processing industries generate large amounts of waste, creating environmental problems; however, these wastes serve as a valuable renewable source of chitin that can be converted into high-value chitosan. The extraction process mainly involves demineralization, deproteinization, and deacetylation. Characterization using techniques such as FTIR, SEM, and thermal analysis helps determine key properties like degree of deacetylation, molecular weight, and stability. Chitosan obtained from freshwater sources shows properties comparable to commercial chitosan, making it suitable for applications in biomedical, food, environmental, and agricultural fields.

**Methods and Material:** Fish scales were collected from the local market, and were washed thoroughly with tap water followed by distilled water to remove any impurities. The cleaned scales were kept in hot air oven at 60$^{o}$c for 48 hours to remove excess water. For further processing, the sample was subjected to three sequential steps, namely, demineralization, deproteinization and deacetylation.

For demineralization, the dried scales were treated with 0.1N HCl and heated at 90$^{o}$c for 15 minutes to remove calcium carbonate and other mineral components. Thereafter, the treated sample was washed with deionized water. To eliminate the protein impurities, the sample was further treated with 1%(w/v) NaOH at 100$^{o}$c for 15 minutes followed by washing with deionized water. Purified chitin was treated with 15% NaOH for the deacetylation process, at 60$^{o}$c for 15 minutes, followed by rinsing with deionized water to obtain chitosan.

**Result and Discussion:** The extracted chitosan from the fish scales was dissolved completely in 1% glacial acetic acid which indicated proper deacetylation. Minimal residual odour and discoloration indicated successful purification. This process gave a yield of chitosan, with an efficacy of 13.2%, appearing as an off-white-coloured powder with minimal residue.

Extracted chitosan was characterized by Fourier-Transform Infrared Spectroscopy (FT-IR) assay. FT-IR analysis showed the presence of characteristic functional groups which corresponded to chitosan. The observed absorption bands also confirmed the successful conversion of chitin to chitosan.

Further the sample was analysed using Scanning Electron Microscopy (SEM), which demonstrated typical surface morphology corresponding to chitosan confirming its successful extraction.

**Conclusion:** The study demonstrated that chitosan can be effectively extracted from fish scale waste following a simple procedure. This work has focussed on utilizing the waste sources for the preparation of chitosan reducing the accumulation of solid waste generated from food processing industries, hence supporting the principles of circular economy.

**Keywords:** Chitosan, Deacetylation, Deproteinization, Demineralization, Plasticizer.

# PP-11: Screening and Biochemical Characterization of Indigenous Monocrotophos-Degrading Bacteria Across Variable Concentration Levels

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**Introduction:** Monocrotophos (MCP) is a highly toxic organophosphate insecticide widely used in agriculture, particularly in developing countries, leading to severe environmental and public health concerns due to its persistence, bioaccumulation potential, and neurotoxicity. Conventional physicochemical remediation methods are costly and often generate secondary pollutants. Microbial bioremediation has emerged as an eco-friendly and sustainable alternative for detoxifying organophosphate contaminants. The present study focused on the screening, isolation, biochemical characterization, and evaluation of monocrotophos degradation efficiency by indigenous bacterial isolates under varying pesticide concentrations, with the objective of identifying efficient microbial candidates for bioremediation applications.

**Materials and Methods:** Soil samples from pesticide-exposed agricultural fields of districts of Odisha were subjected to enrichment culture using minimal salt medium supplemented with monocrotophos as the sole carbon source. Morphologically distinct bacterial colonies were isolated, purified, and screened for MCP tolerance and degradation capability using agar well diffusion, disc diffusion, and minimum inhibitory concentration (MIC) assays. Biochemical confirmation of degradation potential was carried out through organophosphate hydrolase (OPH) activity assays by measuring phosphate release spectrophotometrically (230nm). Quantitative MCP degradation efficiency was determined through UV–visible spectrophotometric analysis across a concentration range of 25–125 ppm over an 8-day incubation period.

**Results and Discussion:** Enrichment culture successfully yielded eight distinct bacterial isolates capable of growing in MCP-supplemented media. Among these, isolates designated A, D, and F demonstrated superior growth and tolerance across all tested MCP concentrations. Qualitative screening assays revealed clear turbidity zones and microbial growth halos around MCP-containing wells and discs, confirming active utilization of the pesticide as a carbon source and biodegradative potential. MIC analysis further demonstrated differential tolerance among isolates, with isolate A exhibiting rapid metabolic activity within 24 hours even at the tested highest MCP concentration (125 ppm) compared to isolates D and F. Biochemical characterization of microbial OPH enzyme activity was observed by measuring the release of phosphate due to hydrolysis of organophosphate bonds in MCP-treated samples compared to controls. Maximum enzymatic activity corresponded with higher MCP levels, suggesting enhanced metabolic stimulation under pesticide stress conditions. Complete degradation was achieved at lower concentrations (25 and 50 ppm) within eight days, indicating rapid microbial detoxification capacity. At higher concentrations, degradation efficiency remained substantial, reaching approximately 94% at 100 ppm and over 88% at 125 ppm, reflecting only mild substrate inhibition. These findings highlight the robustness of the selected bacterial strains and their ability to maintain high degradation performance even under elevated contaminant loads. The strong correlation between bacterial growth patterns, OPH activity, and degradation efficiency suggests that enzymatic hydrolysis is the primary mechanism driving MCP biotransformation.

**Conclusion:** The study successfully isolated and screened indigenous bacterial isolates capable of efficient monocrotophos degradation. The isolates demonstrated high tolerance and degradation efficiency across a broad concentration range, with complete removal at lower pesticide levels and substantial degradation at higher concentrations. These findings underscore the potential of the selected strains as promising candidates for sustainable bioremediation of organophosphate-contaminated soil.

**Keywords:** Monocrotophos; Bioremediation; Organophosphate hydrolase; Bacterial degradation; Pesticide detoxification.

# PP-12: Phytochemical Profiling and Biogenic Synthesis of Copper Oxide Nanoparticles from *Lantana camara* Leaves

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**Introduction:** Plant-mediated nanotechnology has emerged as a sustainable alternative to conventional chemical synthesis due to its eco-friendly, cost-effective, and non-toxic nature. Medicinal plants rich in secondary metabolites act as natural reducing and stabilizing agents in nanoparticle synthesis. These bioactive compounds not only possess therapeutic value but also exhibit insecticidal properties, including anti-oviposition effects, growth inhibition, and toxicity against agricultural pests. The development of plant-based nanoparticle bioinsecticides offers a promising eco-friendly alternative to synthetic agrochemicals. The present study aimed to comparatively evaluate phytochemical extraction efficiency using maceration and ultrasound-assisted extraction techniques, quantify major phytoconstituents, and investigate the green synthesis of copper oxide (CuO) nanoparticles using leaf extracts of *Lantana camara*.

**Materials and Methods:** Fresh leaves of *L. camara* were collected, shade-dried (24–48 h), and powdered prior to extraction. Two extraction techniques i.e maceration (MAC; 30°C for 72–96 h) and ultrasound-assisted extraction (UAE; 40 kHz, 100 W for 2 h) were employed using aqueous and ethanolic solvents. Qualitative phytochemical evaluation of major secondary metabolites was performed. Quantitative analysis included determination of total phenolic content (TPC) using the Folin-Ciocalteu method and total flavonoid content (TFC) using the aluminium chloride spectrophotometric assay. Green synthesis of CuO nanoparticles was carried out via bio-reduction of copper sulphate solution using plant extracts under ambient conditions. The synthesized NPs were characterized by UV-Visible spectroscopy and XRD to analyze structural and crystalline properties.

**Results and Discussion:** Extraction efficiency varied significantly between methods and solvents. Maceration with distilled water produced the highest extract yield (19.97%), whereas UAE yielded lower extract mass (7.51%), reflecting differences in extraction kinetics. Despite lower mass recovery, UAE demonstrated superior efficiency in extracting bioactive compounds due to cavitation-induced cell wall disruption. Qualitative phytochemical screening exhibited the richness of alkaloids, phenolics, flavonoids, tannins, terpenoids, and saponins in all extracts. Quantitative analysis showed TPC ranging from 52.00 mg/g in aqueous macerated extracts to 97.44 mg/g in ethanolic UAE extracts, indicating enhanced phenolic recovery through ultrasonication. TFC ranged from 79.00 mg/g to 183.33 mg/g, with ethanolic maceration showing the highest flavonoid content, highlighting the influence of solvent polarity. Successful green synthesis of CuO nanoparticles was confirmed by visible colour changes from light blue to dark green or brown, indicating reduction of $Cu^{2}z$ ions. Nanoparticle yield was highest in UAE–ethanolic extracts (128.71%), followed by MAC–aqueous (61.17%) and MAC–ethanolic (24.45%), demonstrating a strong correlation between phenolic content and reduction efficiency. XRD analysis confirmed the formation of monoclinic crystalline CuO nanoparticles with characteristic diffraction peaks and an average crystallite size of ~33 nm, indicating nanoscale formation and structural purity.

**Conclusion:** The study demonstrates that *Lantana camara* leaf extracts are rich in phytochemicals and serve as effective bioreductants for green synthesis of CuO nanoparticles. Ultrasound-assisted extraction significantly enhances phenolic recovery and nanoparticle yield despite lower extract mass, establishing it as a superior eco-friendly technique. These findings highlight the potential of plant-mediated CuO nanoparticles for sustainable nanotechnology and bio-based agrochemical applications.

**Keywords:** *Lantana camara*; phytochemicals; ultrasound-assisted extraction; green synthesis; copper oxide nanoparticles.

# PP-13: Identification of Novel Antidiabetic Leads from *Sonneratia* species: An Integrated *in Silico* ADMET and Molecular Docking Study

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**Introduction:** Type 2 diabetes (T2D) is a chronic metabolic disorder characterized by impaired insulin secretion and insulin resistance. In 2024, diabetes affected approximately 589 million adults worldwide (11.1% of the adult population), and this prevalence is projected to rise to 853 million by 2050, with nearly 90% of cases classified as T2D. The rapidly increasing global burden of T2D poses a major public health challenge. A wide range of antidiabetic agents with diverse mechanisms of action are available, many are associated with adverse effects that compromise patient compliance and quality of life. To overcome these limitations, novel therapeutic strategies, targeted drug delivery systems and the development of new drug classes are explored to improve therapeutic efficacy while minimizing side effects. This study aimed to evaluate the antidiabetic potential of plant derived phytochemicals from mangrove *Sonneratia*-species using an integrated *in-silico* studies. The genus Sonneratia (family *Lythraceae*) comprises true mangrove species, including *Sonneratia ovata, S. apetala, S. caseolaris, and S. alba*, and known for its rich metabolites with significant therapeutic potential.

**Methods and materials:** *In-silico* studies have emerged as essential tools in modern drug discovery, reducing the need for extensive compound synthesis and experimental screening. Computational tools and predictive models are widely used to evaluate ADMET (absorption, distribution, metabolism, excretion, and toxicity) properties, while structure-based molecular docking is employed to predict interactions between candidate compounds and biological targets. Additionally, in-silico evaluation of physicochemical properties including, molecular size, lipophilicity, solubility, polarity, flexibility, saturation, drug-likeness, and bioactivity, provides valuable preliminary insights into the drug potential of candidate molecules during the early stages of drug development

**Result and Discussion:** A total of 69 phytochemicals reported from different Sonneratia species were retrieved from the PubChem database for comprehensive computational screening. Toxicity-risk assessment using DataWarrior revealed that 42 phytochemicals showed no toxicity-risk alerts. SwissADME analysis evaluated lipophilicity, solubility, pharmacokinetics, drug-likeness, and medicinal-chemistry parameters, resulting in the shortlisting of 6 compounds. PASS Online prediction indicated moderate antidiabetic potential with Pa > 0.600. Molecular docking was performed against key proteins involved in T2D-related pathways, including PI3K, AKT, mTOR, AMPK, insulin resistance-associated proteins, with a key enzymes á-amylase, á-glucosidase, and DPP-4, which regulate blood glucose levels. Ramachandran plot analysis confirmed the structural viability and stereochemical quality of the target proteins. Docking results demonstrated that the shortlisted compounds exhibited moderate binding energies ranging from e7.5 to e12.0 kcal/mol and formed hydrogen-bond interactions with critical amino acid residues of the respective target proteins.

**Conclusion:** The six shortlisted compounds exhibited low-toxicity, favorable-ADME properties, good oral bioavailability, and strong predicted biological activities. These findings highlight the therapeutic potential of Sonneratia species as promising antidiabetic lead compounds for antidiabetic drug development. Further in-vitro and in-vivo validation is required.

**Keyword:** ***T2D, Sonneratia-species, Pharmacokinetic, Drug-Likeness, ADME, Ramachandran plot, Molecular Docking***

# OP-14: Zeros of Random Polynomials with Weighted Binomial and Geometric Coefficients

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**Introduction:** Random polynomials have been a central object of study in probability theory since Kac's pioneering work on the expected number of real zeros. Classical models assume independent identically distributed coefficients, often Gaussian. However, many natural systems involve structured randomness, where deterministic weights such as binomial coefficients or geometric progressions interact with stochastic perturbations. This paper investigates the zeros of random polynomials with weighted binomial and geometric coefficients. We analyze how these structures influence the distribution of real and complex roots, asymptotic behavior, and universality phenomena. By situating the problem within recent developments (2018–2025), we provide a fresh contribution that connects classical theory with modern applications in combinatorics, statistical physics, and random matrix theory.

**Methods and Material:** In this paper Polynomial Models contains Classical Random Polynomial

Binomial-Weighted Random polynomial, Geometric-Weighted Random Polynomial and also combined model. Analytical Tools used Probabilistic estimates of real roots using sign-change methods, Asymptotic analysis for large degree n, Numerical simulations to visualize root clustering & Comparative framework linking results to universality in random matrices.

**Results and Discussion:** Classical Kac result: expected number of real roots grows like $\frac{2}{\pi} log n$ .Binomial weighting: concentrates roots near [-1,1], reducing spread. Geometric weighting: distribution shifts depending on r; for r>1, roots cluster near the unit circle, while for r. Combined model: hybrid clustering, balancing binomial symmetry with geometric bias. Asymptotic Behaviour Binomial models approximate Gaussian distributions via the central limit theorem. Geometric models exhibit exponential scaling, with critical transitions at r=1.Combined models demonstrate interplay between combinatorial and exponential growth.

**Conclusion**: We analyzed zeros of random polynomials with weighted binomial and geometric coefficients, highlighting how deterministic structures alter root distributions and asymptotic behavior. These models generalize classical random polynomials, revealing new clustering phenomena and universality connections. Future work includes rigorous probabilistic bounds, deeper links to spectral theory, and computational experiments to validate theoretical predictions.

**Keyword:** Random polynomials, Binomial progression, Geometric progression, weighted coefficients, Real roots, Probability theory, Asymptotic analysis.

# OP-15: Expected Number of Level Crossings of a Random Orthogonal Polynomial

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**Introduction**: The study of the distribution of real roots of random algebraic polynomials has been a significant area of research in probability and mathematical analysis. While much work has been done on polynomials with independent identically distributed (i.i.d.) coefficients, this research focuses on random orthogonal polynomials, specifically normalised Legendre polynomials. The primary objective is to determine the expected number of K-level crossings—the number of times the random polynomial P(x) crosses a constant level K—within a specific interval. This study investigates the conditions under which the asymptotic behaviour of these crossings remains invariant relative to K.

**Materials and Methods**: The methodology employs a sequence of normalised Legendre polynomials $T_n^*(x)$ that are orthogonal over the interval (-1, 1). The coefficients $g_j$ of the random polynomials are assumed to be independent normally distributed random variables with mean zero and variance one. To estimate the expected number of level crossings EN($\alpha$, $\beta$), the research utilizes the formula developed by Cramer and Leadbetter, as well as extensions of the Kac and Rice formulas. Technical evaluations involve the Darboux-Christoffel formula and the Laplace formula to approximate the values of Legendre polynomials and their derivatives for large n.

**Results and Discussion:** The study establishes a central theorem showing that for any sequence of constants $K_n$ such that $K^2/n$ tends to zero as n tends to infinity, the mathematical expectation of the number of real roots of the equation T(x) = K satisfies the asymptotic relation EN(-1, 1) $\sim n/\sqrt{3}$. This result demonstrates that the behaviour of random Legendre polynomials is more similar to trigonometric polynomials than to standard algebraic polynomials. Specifically, the expected number of K-level crossings is shown to be invariant for any K = O($\sqrt{n}$), indicating a robust oscillatory nature that persists despite small variations in the crossing level.

**Conclusion:** This research provides a definitive asymptotic estimate for the expected number of K-level crossings for random orthogonal polynomials. By demonstrating that the result for K = 0 remains valid for K growing as O($\sqrt{n}$), the study contributes to the classification of different types of random polynomials based on their oscillatory behaviour. The findings suggest that the trigonometric-type behaviour (where EN = O(n)) is a fundamental characteristic of these random orthogonal structures, contrasting with the algebraic-type behaviour where EN = O(log n).

**Keyword**: ***Random Algebraic Polynomial, Legendre Polynomials, Level Crossing, Real Roots, Orthogonal Polynomials.***

# OP-16: Effect of Surface Modification on Sugarcane Bagasse Fibre reinforced Biocomposites

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**Introduction:** The rising expense of fossil fuels and the thermoplastics made from them pushes researchers to consider alternatives. The best substitute for non-biodegradable thermoplastic is natural fibers and the composites made from them. However, natural fiber reinforced composites' high cost and moderate mechanical qualities limit their ability to dominate the biocomposite market. Waste sugarcane bagasse fiber was used in this study to make composites and assess their characteristics.

**Methods and Material:** This study examines the mechanical, morphological, and thermal characteristics of sugarcane bagasse fibres (SCB) reinforced composites after surface treatment of bagasse fiber. Different concentrations (1, 2, 3, 4, and 5 wt.%) of sodium hydroxide were used for surface modification of waste bagasse fiber for different time periods (1, 2, and 3 h). Weight loss, tensile strength, Fourier transform infrared spectroscopy (FTIR), moisture, and scanning electron micrographs (SEM) of alkali treated bagasse fibers were analyzed and reported. Then optimized alkali treated bagasse fiber and raw bagasse fibers were utilized for composite fabrication by compression moulding, respectively. Tensile, flexural, and water sorption of composites of both composites were carried out and reported.

**Result and Discussion:** The bagasse fiber treated with 2% alkali for two hours had the maximum tensile strength (380 MPa) and tensile modulus (1.5 GPa). After being treated with alkali, the smooth SEM micrographs of raw bagasse become rough because the lignocellulosic bonding breaks. Because amorphous lignin and hemicelluloses are removed during alkali treatment, the moisture content of the 2%, two-hour alkali-treated bagasse fibers dropped by 11.23%. The tensile strength of the alkali-treated SCB composite was 32 MPa, while the raw SCB composite's was 24.2 MPa.

**Conclusions:** These results suggest that bagasse fibers should be treated with low quantities of NaOH (<5%). In conclusion, because of their enhanced chemical, physical, and mechanical qualities, alkali-treated SCB fibers have the potential for a number of uses, including the incorporation of these agro-waste fillers into thermoplastic composites. For application in sectors like automotive and aviation, SCB fibers offer an eco-friendly substitute for synthetic fibers when used as reinforcement.

**Key words:** *Sugarcane Bagasse Fiber; Alkali Treatment; Mechanical Properties; Biocomposite*

# OP-17: Between Human and Machine: Literary Interrogations of Technological Power and Agency

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**Introduction:** In an age shaped by algorithms and technological systems, contemporary literature is a vital lens for examining technology's impact on human existence. This study investigates how authors craft narratives about human–machine relationships that probe the boundaries of identity, autonomy, and justice. Using literary criticism, posthumanist theory, and science and technology studies, the research shows how fiction serves both as warning and resource for understanding our technologically mediated world.

**Materials and Methods**: This study uses qualitative textual analysis of selected contemporary literary works: Kazuo Ishiguro's Never Let Me Go and Klara and the Sun, Margaret Atwood's Oryx and Crake and The Handmaid's Tale, Aravind Adiga's The White Tiger and Amnesty, Dave Eggers' The Circle, and Ian McEwan's Machines Like Me. Thematic coding and close reading identify patterns, motifs, and narrative strategies across cultural contexts.

**Results:** The analysis identifies six principal themes. The Machine as Judge explores how algorithmic systems replace human judgment. Language as Control examines how technological discourse transforms communication. Digital Vulnerability addresses exposure of private lives to surveillance and data exploitation. Algorithmic Authority investigates acceptance of algorithmic power as superior to human expertise. Narrative Resistance shows how storytelling resists technological determinism. The Dehumanization of Justice reveals loss of empathy when technology replaces human decision-making. These themes show technology as an active force transforming social relations and personhood.

**Discussion:** These texts function as critical commentaries, examining the ethical consequences of technological systems. By casting technologies as arbiters of fate, authors question the erosion of human agency. Ishiguro's bioengineered characters raise issues of consciousness and exploitation, Atwood's dystopias warn against unchecked scientific development, and Adiga's protagonists show how surveillance reinforces inequality. Literature emerges as cultural critique, challenging technological optimism and making ethical dilemmas tangible through character and narrative.

**Conclusion:** This study shows that literary narrative is essential for understanding technological transformation and its effects on human identity. Fiction offers insight into lived experience of technological change, serving as a laboratory for imagining alternative futures and preserving human experience beyond algorithmic logic. This research contributes to interdisciplinary scholarship at the intersection of literary studies, posthumanist theory, and technology ethics, affirming the importance of humanistic inquiry for grasping technology's impact on agency, identity, and social justice.

**Keywords**: Technology, Literature, Human–Machine Relationships, Posthumanism, Textual Analysis, Ethics of Technology

# OP-18: Crystal structure refinement, Optical and Dielectric investigations of $ErFeO_3$ substituted $CoFe_2O_4$ for Potential Industrial Applications

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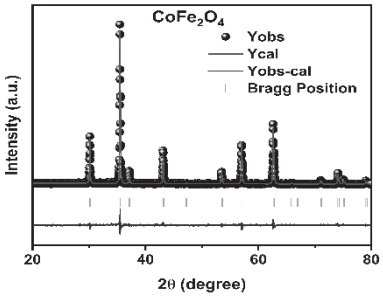
**Introduction:**Spinel ferrites have general formula $AB_2O_4$, where A type kind atoms occupy the tetrahedral position, B type in the octahedral position. Their properties and cationic arrangement at sites are strongly correlated. These materials find widespread applications due to their excellent electrical, optical and magnetic aspects in data storage, optoelectronic devices, gas sensors, microwave absorption, etc. Incorporating ErFeO*f* into spinel ferrite materials is done to tailor their optical,dielectric and magnetic properties. The presence of Er³z ions (large ionic radius compared to Fe³z ) can influence cation distribution between tetrahedral (A) and octahedral (B) sites in the spinel lattice, leading to modified superexchange interactions between Fe³z ions.

**Methodology:** A series of composite samples of $(1-x)CoFe_2O_4$-$xErFeO_3$ with variousweight fractions of x = 0, 0.02, 0.06 have been synthesized using solid-state reaction method. The calcination and sintering temperature of all the samples are 1000°C and 1050°C respectively.

**Result and Analysis:** Rietveld refinement of X- ray diffraction plot confirms that the material crystallize in a cubic spinel structure (Fd-3m space group) for x = 0. For the different composite samples (x=0.02, 0.06), the phase analysis confirms that the obtained samples possess the two phases: perovskite $ErFeO_3$ and spinel $CoFe_2O_4$. The band gap shows an increasing trend after substituting $ErFeO_3$ and exhibits higher resistive semiconducting properties. The variation in band gap for different substitutions is related to the degeneracy of the doping level.The variation of dielectric constant (åc") with frequency is explained by Maxwell–Wagner interfacial polarization and Koop's theory. The variation of dielectric loss with temperature demonstrates that moderate Er–Fe substitution effectively suppresses dielectric loss, thereby improving the high-temperature performance and suitability of $CoFe_2O_4$ceramics for capacitor, actuator and energy-storage applications.




**Conclusion:** The structural changes are accompanied by a systematic increase in band gap from 2.07 eV to 2.47 eV with increasing doping concentration from 0.00 to 0.06. The electron accumulates at the grain boundaries by the hopping mechanism because of the insulation property of grain boundary, which leads to the polarisation. The results establish that presence of Er-Fe in spinel ferrite provides a versatile route to engineer with tuneable dielectric, insulating, optical responses, enabling their application in advanced capacitors, actuators, optoelectronic systems, and multifunctional devices.

**Keywords:**Spinel Ferrite; UV Vis Spectroscopy; Dielectric loss.

# OP-19: Application of Simplex Method on Agriculutre

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**Introduction:** Agriculture is a vital sector of the economy, where the efficient utilization of limited resources such as land, labor, water, and capital plays a crucial role in maximizing profit. Mathematical optimization techniques, particularly linear programming using the Simplex method, provide a systematic and effective approach to agricultural decision-making. In this study, an agricultural planning problem is formulated with the objective of maximizing profit subject to various resource constraints. The model is solved using both the Simplex method and the programming tool MATLAB. The results highlight the importance of optimization techniques in improving economic outcomes, ensuring efficient resource allocation, and supporting sustainable and profitable agricultural management.

**Methods and Materials:** The Simplex method is applied as a systematic optimization technique to support decision-making in the agricultural sector by maximizing profit under limited resources. In this methodology, agricultural activities such as crop production are first identified, and decision variables are defined to represent the level of each activity. An objective function is then formulated to maximize total net profit obtained from these activities. Resource constraints such as availability of land, labor, capital, water, and other inputs are mathematically expressed as linear inequalities. Non-negativity constraints are imposed to ensure practical feasibility of the solution. The formulated linear programming problem is converted into standard form and solved using the Simplex method through iterative pivot operations to obtain the optimal solution. The results provide the optimal allocation of resources among different agricultural activities, ensuring maximum profitability and efficient resource utilization. This methodology helps farmers and planners evaluate alternative production strategies and make informed decisions under resource constraints.

**Result and Discussion**: In this study, a linear programming model was developed to maximize agricultural profit under various resource constraints such as land availability, labor, and capital. The objective function represented the net profit obtained from different agricultural activities, while the constraints ensured realistic limitations on available resources. The optimization problem was solved using both the Simplex method and MATLAB. The results obtained from both methods were consistent, with the maximum achievable profit found to be **44 units**. This agreement between the manual Simplex method and MATLAB output validates the correctness of the model and highlights the efficiency of computational tools. The use of programming software like MATLAB significantly reduces computational errors and saves time, especially when dealing with complex problems involving multiple crops and constraints.

**Conclusion:** The study demonstrates that linear programming is a powerful and effective tool for agricultural decision-making. By optimally allocating limited resources, it helps farmers and planners determine the best production strategies to maximize profit and productivity. The successful application of both the Simplex method and MATLAB confirms the reliability of linear programming models in solving agricultural optimization problems. Overall, the approach provides valuable support for efficient resource management and informed decision-making in agriculture under resource constraints**.**

**Keyword: Maximum Profit, Linear Programming Problem, Optimum solution, Simplex method.**

# OP-20: Improved Dielectric and Magnetic behaviour of rare earth doped spinel ferrite for Microwave Application

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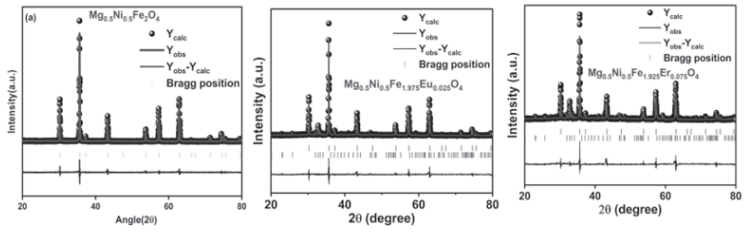
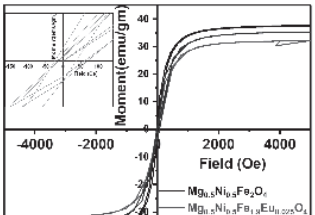
**Introduction:** Ferrites are widely used in microwave devices due to their unique magnetic and electrical properties, including high electrical resistivity, high permeability, low eddy current losses, and strong electromagnetic coupling. Their structural and electromagnetic properties are strongly influenced by synthesis route, composition, calcination, and sintering condition. Rare-earth doping, such as Eu³z substitution for Fe³z , modifies the super-exchange interactions and enhances electromagnetic performance.

**Methodology:** The polycrystalline ferrites $Mg_{0.5}Ni_{0.5}Fe_{1-x}Eu_xO_4$(x = 0, 0.025, 0.075) were synthesized using the solid-state reaction route.

**Result and Analysis:** Rietveld refinement confirm that the materials crystallize in a cubic spinel structure (Fd-3m) for x = 0, with a lattice parameter of 8.3544 Å. Eu³z substitution induces a secondary perovskite phase due to limited solubility. The co-substitution process with Europium ions produces $E_g$ data almost in same order as the parent sample. The $E_g$ of Eu doped MgNi ferrite enhances with an increase in Eu concentration $Mg_{0.5}Ni_{0.5}Fe_{1-x}Eu_xO_4$(x = 0, 0.025, 0.075). The variation of dielectric constant (åc") with frequency shows a sharp decrease at low frequencies followed by a nearly constant value at higher frequencies. This typical ferrite behavior is explained by Maxwell–Wagner interfacial polarization and Koop's theory. The undoped Mg€ …. Ni€ …. Fe, O,, sample exhibits the highest dielectric constant (åc" > 120 at low frequency), while Eu³z -doped samples show significantly lower values (5–40). Eu³z substitution at the Fe³z site modifies the Fe²z /Fe³z ratio and reduces electron hopping, thereby decreasing space-charge polarization. Consequently, å2 decreases with increasing Eu³z content, with minimal effect in the high-frequency region. Eu³z substitution strongly affects dielectric loss: Eu-rich samples, particularly Mg€ …. Ni€ …. Fe .‰ $_{25}$Eu€ $_{.075}$O,, , show the highest tan/ ä (~0.4), while undoped and lower-doped samples exhibit lower values (~0.05–0.3). The magnetic plots show a decreasing trend in saturation magnetization, which can be attributed to the reduction of sublattice magnetic moments. Conversely, there is an increasing trend in coercivity, likely due to the enhancement of magnetocrystalline anisotropy. These behaviors are characteristic of soft magnetic materials.




**Conclusion:** Confirmation of precise synthesis and structural analysis was performed using the least-square approach. The M-H loops show the soft ferromagnetic behaviour of the material under investigation. The ferrites exhibit strong reflection loss, wide absorption bandwidth, and stable performance confirming their suitability for next-generation electromagnetic interference (EMI) shielding and microwave absorber.

**Keywords:** Reitveld Refinement, Dielectric loss; Reflection loss; Magnetic Hysterisis

# PP-21: Harnessing the potential of Chitosan Schiff base nanocomposite hydrogel towards effective catalytic degradation of organic pollutants

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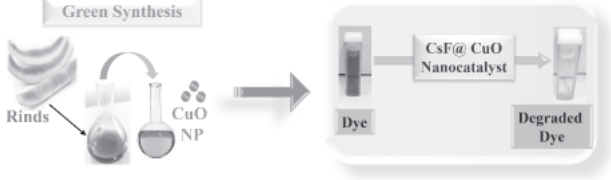
**Introduction:** Rapid industrialization, urbanization, agricultural and population expansion, has invariably led to an alarming increase in the release of harmful contaminants like heavy metals, organic and inorganic pollutants, dyes etc. into the environment. Many methods have been employed for the mitigation of such pollutants wherein catalytic reduction using nanoparticles has gained thrust lately owing to its simplistic approach, economical, high efficiency, use of lesser quantity of solvent and shorter reaction time. CuO nanoparticles (NPs) have ensured potential in different fields including environmental remediation. With the current focus on green chemistry; CuO NPs have also been prepared by green methods *via* plant mediated extracts as the process is environmentally benign. The plant extract containing bioactive metabolites behave as reducing and capping agent and aid in the reduction the metal salts to their corresponding NPs. Nanocomposite hydrogels formed by the addition of NPs onto polymeric hydrogels exhibit an inimitable class of material for environmental remediation.

**Materials and Methods:** Watermelons were purchased from local markets in Bhubaneswar. HCHO, $NaBH_4$ and $CuSO_4$ were procured from Merck India Ltd. Chitosan and dyes were obtained from Sigma-Aldrich (India). Green synthesis of CuO NPs was accomplished using watermelon rind extract. Cs- HCHO (CsF) hydrogels were synthesized by Schiff base reaction. CsF@ CuO nanocomposite hydrogel was prepared by the solvent casting method. Different analytical techniques such as FTIR, XRD, DLS, FESEM, TGA were carried out and dye removal was studied by UV-Vis spectrophotometry.

**Results and Discussion:** Green synthesis of the NPs was accomplished from waste watermelon rind extract. The formation of CuO NPs was ascertained from FTIR and XRD studies. Spherical CuO NPs having an average particle size of 26.8 nm was accomplished. A zeta potential of –23.1 mV was obtained for the CuO NPs. The FTIR spectral data suggested the hydrogel formation and effectual inclusion of CuO NPs in the CsF@ CuO hydrogel. A slight better thermal stability could be noted for CsF@ CuO hydrogel in comparison to CsF hydrogel. The CsF hydrogel possessed a porous morphology whereas the CsF@ CuO nanocomposite hydrogel demonstrated a compressed structure. CsF@ CuO hydrogel demonstrated good catalytic reduction of pollutants rhodamine B and methyl orange in the presence of $NaBH_4$. The apparent rate constant for reduction reaction of RhB and MO was estimated to be 0.135 $s^{-1}$ and 0.099 $s^{-1}$ respectively.

**Conclusion:** In summary, this study validates two commendable prospects: (i) valorization of waste watermelon rind towards the green synthesis of nanoparticles and (ii) fabrication of a sustainable CsF@ CuO nanocomposite hydrogel for efficient reduction of hazardous anthropogenic water pollutants in wastewater treatment.

**Keywords:** Green synthesis, Schiff base hydrogel, dye reduction



# PP-22: Facile Synthesis and Characterization of Iron Oxide Quantum Dots

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**Introduction:** Quantum dots are semiconductor nanocrystals measuring only a few nanometers, whose electrical and optical properties, such as discrete energy levels and size-tunable photoluminescence, stem from quantum mechanical phenomena that significantly differ from those of bulk materials. Iron oxide quantum dots (IOQDs) represent a category of nanoscale materials that integrate the distinctive quantum confinement features with the magnetic and biocompatible attributes. When iron oxide, usually as magnetite (Fe*f* O,, ) or similar phases, is fabricated at the quantum-dot scale, the resulting IOQDs demonstrate magnetic responsiveness and luminescent properties, rendering them suitable for multifunctional applications in bioimaging, targeted drug delivery, magnetic separation, and advanced sensing. Their diminutive dimensions, elevated surface-to-volume ratio, and adjustable surface chemistry further facilitate their incorporation into biological and technological systems, where the amalgamation of optical and magnetic functions is advantageous.

**Methods and Materials:** Ferric chloride (AR grade, Merck, India) and ammonium hydroxide (98%, Loba) were used for synthesis, with Millipore distilled water as a solvent. A new method for synthesizing IOQDs involves a one-pot co-precipitation method at low temperature, resulting in QDs ranging from 5-8 nm in size. Various analytical techniques, such as XRD, FESEM, and UV-visible spectroscopy (DRS), were applied to characterize the QDs.

**Result and Discussion:** The d-spacing of IOQDs is calculated from the XRD peaks at ë = 0.15406 nm using Bragg's equation. The synthesized IOQDs are compared with the PDF data from theInternational Centre for Diffraction Data. The PDF data file No: 96-210-1169 ($Fe_{12}$ $O_{18}$, Hexagonalare used to determine the Miller indices. Nineteen peaks between 20° and 90° in the PXRD data show the crystalline nature of the IOQDs, which matches the PDF data, confirming their composition. The FESEM data supported the IOQDs' small, spherical, homogeneous shape with a size of 5 - 8 nm. The IOQDs exhibit a band gap energy of S 4.31 eV, indicating that they are semiconductors.

**Conclusion:** A new low-temperature one-pot co-precipitation method synthesizes iron oxide quantum dots (IOQDs) with sizes ranging from 5-8 nm. Characterization techniques such as XRD, FESEM, and UV-visible spectroscopy were employed. XRD analyses confirmed the crystalline nature of the IOQDs. The IOQDs exist as small, spherical shapes with a band gap energy of ~ 4.31 eV, classifying them as semiconductor materials.

Future research should focus on enhancing the surface functionalization and biocompatibility of iron oxide quantum dots to improve their targeted biomedical applications and enable scalable, safe clinical translation.

***Keywords: Quantum Dots, Iron Oxide Quantum Dots, Co-Precipitation, Low-Temperature.***

# PP-23: Biopolymer-based edible coating enriched with orange peel essential oil: Application in chicken meat preservation

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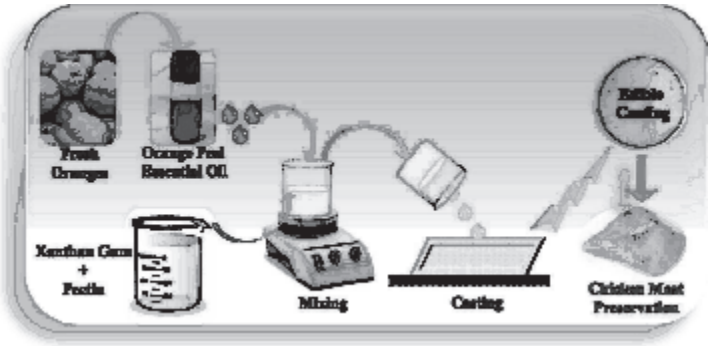
**Introduction:** Food packaging materials have grown at an astonishing pace due to the food industry's explosive growth, modern lifestyle, and growing need for meals at home. Synthetic plastic is the most widely used material for food packaging but have resulted in significant environmental issues due to their non-sustainable origins, non-recyclability and non-biodegradability. Biopolymer coatings in food preservation help to extend food shelf life, restrict microbial development, manage moisture and oxygen permeabilities, and are biodegradable and biocompatible. Pectin is used mostly as a gelling, thickening, and stabilising ingredient in the food industry. The properties of the pectin coatings are improved by xanthan gum with thickening, stabilising, and emulsifying properties. Essential oils, as bioactive agents, have been added to such films to improve their efficacy in food preservation.

**Materials and Methods:** Sweet oranges were procured from local markets in Bhubaneswar, Odisha. XG and pectin were obtained from Sigma Aldrich, India. Glycerol and Tween 80 were brought from SRL India and used as such. ABTS and DPPH were received from Himedia, India. Orange oil was extracted by hydrodistillation method. Different analytical techniques were used for characterization.

**Results and Discussion:** EOs were extracted from orange peels revealed D-limonene (71.22%) as the major component. The suc-cessful infusion of EO was observed from FTIR and XRD studies. The EO incorporation dose-dependently improved the thickness, tensile strength, porosity and hydrophobicity of the films. On the other hand, a lowering in water solu-bility, moisture content, oxygen and water vapor permeabilities were noted with increasing EO content in the films. The EO-infused films displayed a slightly lower degradation temperature with respect to pristine PecXG film. The film with highest EO demonstrated significant UV-shielding properties. The inclusion of EO promoted the antioxidant activity of the films. Meat sample coated with the EO-infused films displayed lower changes in pH, weight loss and total volatile basic-nitrogen in comparison to uncoated sample during the stor-age tenure of 10 days. Furthermore, the prepared coatings were biocompatible with L929 cells.

**Conclusion:** In summary, this study validates certain commendable prospects: (i) Orange peel EO was extracted by the environmentally benign by ultrasound-assisted hydrodristillation method; (ii) natural polysaccharide-based PecXG films infused with varied EO content were developed that were biocompatible and (iii) that the designed films in this work have a high potential to maintain and improve the quality of raw chicken during cold storage.

**Keywords:** Sweet orange essential oil, Edible coating, Pectin, Xanthan gum, Meat packaging



# PP-24: Computational Insights into the Kinetics and Mechanism of $Mn^{III}(salpd)(OH_2)_2^+$complex Reduction by Oxalic Acid: Role of the Methylene Spacer

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**Introduction:** Superoxide dismutase and catalase are two important enzymes, consisting of manganese complexes, present in the human system. These enzymes can protect cells from oxidative damage, improve mitochondrial function, and exhibit photoactivity for the evolution of oxygen when exposed to visible light. Hence underdstanding the mechanism of substitution reactions of manganese complexes always becomes more interesting. In continuation of our efforts to unravel the substitution mechanisms of manganese complexes, we herein report: (i) a detailed kinetic study of $Mn^{III}(salpd)(OH_2)_2^+$complex, and DFT calculations aimed at understanding the transition states and intermediates involved in the substitution reactions.

**Methods and Materials:**$[Mn^{III}(salpd)(H_2O)_2]ClO_4.H_2O$ complex was synthesized using Schiff base ligand ($H_2$salpd = *N, N*′-bis(salicylidene)propane-1,3-diamine) following the reported procedure. The kinetic studies have been performed at various temperatures (25 - 40ÚC) within the pH range of $2.8 < pH < 4.9$. To determine the degree of distortion in the complex's octahedral geometry and its impact on the redox process, the structure of the complex and its analogues were optimized using DFT.

**Result and Discussion:** The time-dependent repetitive spectral scans of the complex in the presence of oxalic acid at pH 2.7-5 show the gradual decrease in absorbance with time at 280 nm, due to the reduction of $Mn^{III}$ to $Mn^{II}$ by oxalate species. The end product, i.e., formation of $Mn^{II}$ is proved by six line EPR spectrum. The pseudo-first-order rate constants are collected at 25 - 40ÚC with varying reaction conditions. Based on the kinetic data, a plausible reaction mechanism is proposed. The DFT studies are applied to support the proposed intermediates, which support the reaction mechanism.

The reduction of $Mn^{III}$ in $Mn^{III}(salpd)(OH_2)(HOX)$ by $HOX^-$ ($k_1$ path) is the major reaction pathway in which $HOX^-$ is a better-reducing agent than $H_2OX$. The bioxalato species ($HOX^-$) is a better electron donor in comparison to its conjugated acid analogue, $H_2OX$. However, higher $k_{obs}$ for reduction at lower pH indicate that reduction also proceeds by $H_2OX$ ($k_2$ path) in addition to the acid-catalysed decomposition of the complex. The reaction precedes, preferably, via an efficient inner-sphere electro-protic reaction involving the proton-coupled electron transfer (PCET) process. The rate constants of both Schiff base $Mn^{III}$ complexes, *salen* and *salpd*, are compared, and the significant role of the methylene spacer was confirmed.

**Conclusion:** The reaction between $Mn^{III}(salpd)(OH_2)_2^+$ and oxalate species ($H_2OX$, $HOX^-$ and $OX^{2-}$) is preceded by fast and reversible aqua ligand substitution by $HOX^-$ resulting in the formation of monodentatebioxalato analogue, *trans*-$Mn^{III}(salpd)(OH_2)(HOX)$. The bioxalato analogue and its conjugate acid analogue, $Mn^{III}(salpd)(H_2O)(OX)^-$ are kinetically inert to the intramolecular reduction of the $Mn^{III}$center by the coordinated bioxalato/oxalate species. Structural optimization by DFT shows that the *salpd*-diaqua analogue suffers more distortion in the square planar structure ($N_2O_2$) around the $Mn^{III}$center than its *salen* analogue due to the introduction of a methylene spacer as in *salpd*. The computational study and analysis of rate data supported that the electron transfer occurs through $k_1$ and $k_2$ paths, and the latter path is essentially a proton-controlled electron transfer (PCET) process.

***Keywords: Oxalate, Manganese complex, DFT, PCET.***

# PP-25: Fabrication of Nanocomposite (CuS-g$C_3N_4$ ) For Photocatalytic Energy Application

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**Introduction:** Efficient and sustainable nanocomposite materials have attracted significant interest for their broad applications in energy storage, environmental remediation, and sensing technologies. In this, a nanocomposite of CuS/ g-$C_3N_4$was successfully prepared and studied in terms of its multifunctionalities. Graphitic carbon nitride (g-$C_3N_4$) is a semiconductor, metal-free polymeric material with high chemical stability, low cost, and visible-light response, but its performance in practice is impaired by rapid electron-hole recombination. To overcome this limitation, copper sulfide (CuS), a narrow band-gap semiconductor with excellent electrical conductivity and visible-light absorption, was coupled with g-C*ƒ* N,, to form an efficient hetero-structured nanocomposite.

**Material and Methods:** Synthesis comprised of two steps. The individual precursors were first of all prepared separately. The micro-flowers of copper sulfide (CuS) were prepared by a sonochemical process in which copper sulfate pentahydrate and thiourea were taken as precursors, along with citric acid used as the complexing and morphology-directing agent. Sonication favored fast nucleation and homogeneous growth of microstructures of CuS. Graphitic carbon nitride (g-$C_3N_4$) was prepared through a single-step pyrolysis reaction involving melamine, urea, and thiourea as nitrogen-containing reagents. The thermal condensation produced a layer of g-$C_3N_4$ with improved surface area and appropriate electronic characteristics. The CuS/ g-$C_3N_4$nanocomposite was then prepared, with the CuS added on the g-$C_3N_4$ , so that intimate contact between the two elements takes place.

**Result and Discussion:**The resulting CuS/g-C*ƒ* N,, nanocomposite demonstrated significantly improved functional performance compared to the individual materials. The formation of a heterojunction between CuS and g-C*ƒ* N,, effectively suppressed electron–hole recombination and enhanced charge separation, leading to improved photo-induced activity under visible-light irradiation. These properties make the composite highly suitable for photocatalytic water splitting, where enhanced hydrogen generation was observed due to efficient charge carrier migration. Additionally, the nanocomposite exhibited promising performance in electrochemical supercapacitor applications, showing increased specific capacitance and improved charge storage behavior attributed to the synergistic interaction between CuS and g-C*ƒ* N,, . The material also demonstrated potential as a sensor for heavy metals and environmental pollutants, owing to its improved electrical conductivity and surface reactivity. Furthermore, the CuS/g-C*ƒ* N,, nanocomposite displayed notable antibacterial activity, which is primarily associated with the generation of reactive oxygen species (ROS) under light irradiation, leading to effective bacterial inactivation.

**Conclusion:** The synthesized CuS/g-C*ƒ* N,, nanocomposite represents a sustainable visible-light-driven photocatalyst with enhanced charge separation, reduced recombination losses, and multifunctional applicability. The facile synthesis methods, low-cost precursors, and excellent performance highlight the potential of this nanocomposite for future applications in energy conversion, environmental protection, and biomedical fields.

**Keywords:** CuS/g-C*ƒ* N,, nanocomposite; Sonochemical method; Pyrolysis; Visible-light absorption; Suppressed electron–hole recombination; Improved charge separation; Sustainable photocatalyst; Water splitting; Supercapacitor; Antibacterial activity.

# PP-26: Structure, Morphology and Optical Properties of Gadolinium doped Cobalt Ferrite ($CoFe_2O_4$)

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**Introduction:** Spinel ferrites are described by the chemical formula $MFe_2O_4$ where M stands for divalent metal ions. Spinel ferrites draw research interest due to modern applications in industry such as, energy devices, biomedical applications, which include magnetic drug delivery, cancer treatment, and bio-imaging contrast increasing agent. Among the spinel ferrites, cobalt ferrite, $CoFe_2O_4$ exhibit unique properties such as high coercivity, high magneto crystalline anisotropy, high curie temperature, high mechanical and chemical stability. The substitution of rare earth ions into cobalt ferrite structures has been explored to further modify these properties. The large ionic radii and unique magnetic moments of rare earth elements significantly affect the crystal structure and magnetic characteristics of the ferrite. In this study we have investigated the effect of Gd substitution on the structural, morphological, and optical characteristics of $CoFe_2O_4$ prepared solid-state reaction method.

**Materials and Methods:** CoGdxFe2-xO4 (0 d" x d" 0.08) samples were prepared by a high-temperature solid-state reaction method. The as prepared powders are reground and pressed into pellets (10mm in diameter) with 4-5 ton pressure. Structural studies of the samples were carried out using X-ray diffraction (XRD). The micro structure, morphological characterizations were studied using Scanning electron microscope (SEM). Micro Raman measurements were carried out with 632.8 nm He-Ne laser excitation. The optical band gaps were studied using UV–visible diffuse reflectance spectrum (DRS).

**Results and Discussion:** X-ray diffraction patterns of $CoGd_xFe_{2-x}O_4$ powder samples exhibit all major reflection peaks, (1 1 1), (2 2 0), (3 1 1), (4 0 0), (4 2 2), (5 1 1) and (4 4 0), which ascertain face centered cubic structure of cobalt ferrite having space group Fd-3m by comparing with JCPDS card no. (22–1086). From the XRD pattern, the highest peak observed is (311) plane. Moreover, the area under this peak is decreased and width is increased with increasing Gd content, which indicates structural distortion induced by Gd substitution. The crystallite sizes found to decrease with increasing Gd concentration. The Raman modes are observed at around 114.5 $cm^{"1}$, 246 $cm^{"1}$, 421 $cm^{"1}$, and 714.2 $cm^{"1}$ which is in accordance with inverse cubic spinel structure and conform the XRD results of $CoGd_xFe_{2-x}O_4$. The optical bandgap is found to be 1.52 eV which matches with reported value. From SEM analysis the particle size is found to decreases with increasing Gd concentration.

**Conclusions**

Gadolinium doped Cobalt ferrite were successfully synthesized using solid state reaction technique. Their structural, micro structural and optical properties were studied.

**Keywords: XRD; SEM; Raman.**

# PP-27: Experimental and Numerical Investigation of Water Rocket Propulsion : An Aerodynamic Analysis

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**Introduction:** Rocket propulsion fundamentally relies on Newton's Third Law of Motion. In conventional rockets such as the Polar Satellite Launch Vehicle (PSLV), Geosynchronous Satellite Launch Vehicle (GSLV), and Falcon 9 — combustion produces high-velocity exhaust gases which employ chemical propulsion systems. But at the initial stage, our goal is to understand the complex propulsion systems for which we have used compressed water based rockets to provide a simplified yet scientifically rich methodology to study thrust generation, compressible flow dynamics, and projectile motion. This study aims to design, fabricate, experimentally test, and theoretically model a compressed water rocket system, integrating propulsion physics with aerodynamics.

**Methods and Materials:** The rocket airframe was constructed using a 2.25 L Polyethylene Terephthalate (PET) bottle with three triangular fins mounted at 120° separation for aerodynamic stability. A lightweight plastic nose cone (base radius 5 cm, height 10.5 cm) improved streamlining and served as a parachute bay. An octagonal parachute (30 cm diameter) with a 3 cm central spill hole and eight ~100 cm suspension threads was fabricated for controlled descent. An H-shaped launch pad constructed from Polyvinyl Chloride (PVC) pipes ensured vertical alignment and efficient airflow into the nozzle. The dry mass was 53 g. The rocket was filled with 36% water by volume, giving a total launch mass of 0.863 kg. Pressurization was achieved using 11 manual pump strokes (0.07 L per stroke), producing an estimated 4 bar gauge (H"5 bar absolute) internal pressure. Burn duration was approximately 0.35s. Propulsion was modeled using conservation of momentum and Bernoulli's equation to estimate exhaust velocity, assuming isothermal compressed air expansion. Thrust was treated as time-varying due to rapid internal pressure decay during water expulsion.

**Results and Discussion:** A 3D Cartesian coordinate framework was used for trajectory reconstruction. The launch was recorded using a stationary camera placed at a fixed distance from the pad. The video was decomposed into frames, and a pixel-to-meter calibration factor was obtained using known geometric references, including the launch structure height and bottle dimensions. Apogee was identified by detecting the transition from upward to downward motion. The launch direction was approximately 18° toward North-North-East, with a 22 km/h wind from North-East included as a lateral velocity component. The experimental apogee was 16 m, while the no-drag model predicted 36.38 m. The drag coefficient was determined as 0.541.

**Conclusion:** The study successfully integrated theoretical propulsion modeling with experimental 3D trajectory reconstruction, demonstrating the significant role of aerodynamic drag in limiting performance. The methodology establishes a reliable, scalable foundation for future high-power rocketry investigations and refined aerodynamic characterization.

**Keyword:** Water-Rocket Propulsion, Trajectory Reconstruction, Aerodynamic.

# PP-28: Role of $Na^+$ Co-doping on the Structural and Optical Properties of $Ce^{4+}/Dy^{3+}$ Activated $CaZrO_3$

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**Introduction:** The quest for efficient, stable and cost-effective phosphors for solid-state lighting (white light-emitting diodes, w-LEDS) has led to significant research into host lattices that can support rare-earth activation. Perovskite-type inorganic materials ($ABO_3$) have garnered significant attention in the field of luminescence and photocatalysis due to their robust structural integrity and promising optical properties. Among them, Calcium Zirconate ($CaZrO_3$) is a wide band gap dielectric material possessing excellent thermal stability, low phonon energy, chemical inertness and dopant compatibility which makes it an efficient host lattice for rare-earth ion incorporation. In the present work, the structural and optical properties of $Ce^{4+}$/ $Dy^{3+}$ activated $CaZrO_3$ phosphors are systematically investigated with $Na^+$ co-doping to understand its role in charge compensation and luminescence enhancement.

**Methods and Material:** The $Ce^{4+}/Dy^{3+}$ doped and $Na^+$ co-doped $CaZrO_3$ samples were synthesized using the conventional solid-state reaction method. High purity precursor materials such as $CaZrO_3$, $ZrO_2$, $Dy_2O_3$, $CeO_2$ and $Na_2CO_3$ supplied by Sigma Aldrich were taken in stochiometric ratios as primary constituents. The homogenized mixture is thoroughly ground and subjected to calcination for 2 hours at 1000° C. Structural characterization was performed by using X-ray diffraction (XRD) analysis to confirm phase formation and lattice modification and Rietveld refinement was employed to analyze lattice parameters, crystallize size, and microstructural strain. Optical absorption properties were examined through Diffuse Reflectance Spectroscopy (DRS), and the optical band gap was estimated using the Kubelka-Munk function and Tauc's relation.

**Results and Discussion:** XRD analysis confirmed the formation of a single-phase orthorhombic perovskite structure without secondary impurity phases indicating successful incorporation of dopant and co-dopant ions into the host lattice. The investigated $CaZrO_3$ belonging to the Pnma space group with four formula units per unit cell (Z=4) corresponds to 4 Ca, 4 Zr, and 12 O atoms (20 atoms per unit cell). Although $Ca^{2+}$ exhibits 12-fold coordination in the ideal perovskite structure, the tilting of $ZrO_6$ octahedra in the orthorhombic phase associated with a tolerance factor less than unity reduces its effective coordination to a distorted 8-fold (8+4) configuration. Subtle shifts in diffraction peaks upon $Na^+$ co-doping indicate slight variation in lattice parameters due to ionic radius mismatch. Dopant substitution at A-site and B-site generates lattice strain, confirming effective charge compensation by $Na^+$ ions. Optical studies revealed strong absorption in the UV region and a wide band gap characteristic of $CaZrO_3$. The optical band gap values were found to exhibit slight modulation with co-doping which can be correlated to defect-induced localized states.

**Conclusion:** The present research work focuses on investigating the structural and optical modifications induced by $Na^+$ co-doping in $CaZrO_3$ activated with $Ce^{4+}$ and $Dy^{3+}$ ions. It is expected that the introduction of $Na^+$ ion will significantly influence the crystal structure, refine the microstructure, increase the optical band gap and enhance the photoluminescence emission intensity white-light phosphor for future display and lighting devices.

**Keywords: Perovskite hosts, Photoluminescence, Rare-earth doping, Charge compensation**

# PP-29: Structure-property correlation in $Dy^{3+}/Sm^{3+}$ co-doped barium zirconate perovskite systems

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**Introduction:** Perovskites have been found to be applicable to superconductivity, photocatalysis, electrocatalysis, photoelectric conversion LEDs and other fields. The limited properties of pure-phase perovskites are not sufficient to meet growing technical and performance requirements. Thus, experimental research has increasingly focused on doping modification of crystal chemistry, there by tuning the material property for specific device application. The co-doping of rare earth ions: $Dy^{3+}$ and $Sm^{3+}$ into $Ba^{2+}$ site of barium zirconate (BZO) can induce oxygen vacancies, there by increasing proton conductivity of BZO based ceramics for potential electrochemical and sensor related applications.

**Materials and Methods:** Dy and Sm co-doped BZO ceramics were fabricated using cost effective high temperature mixed oxide reaction mechanism following the steps: stoichiometric weighing, grinding, calcination, pressing into pellets, and sintering. Phase and symmetry of synthesized ceramics were determined through XRD. Raman spectroscopy complemented XRD by probing disorder and defect sensitive vibrational features linked to oxygen non stoichiometry. UV-Vis analysis provided information regarding the optical band gap of Dy/Sm co-doped $BaZrO_3$ ceramics.

**Results and Discussion:** XRD analysis confirms the Cubic (Pm-3m) structure of undoped and Dy/Sm co doped samples, with no detectable secondary oxides, indicating phase purity and successful incorporation of dopants into A-site of BZO ceramics. With single Sm ion doping, strong lattice contraction is observed from left shifting of (110) peak of parent BZO in Sm-doped BZO. While after 5% Sm doping, further increase in Dy doping at the same site gradually compensates the lattice contraction, retaining the cubic structure of BZO. The crystallite size as well as strain are calculated using Williamson-Hall method. The effect of co-doping on lattice parameters and crystallite size has been realized from XRD study. The broadening of XRD peaks indicates the induced oxygen vacancies due to rare earth co-doping in BZO ceramic. For charge compensation, formation of a coupled set of cation defects and oxygen vacancies supports mixed ionic-electronic conduction in these doped ceramics. Raman interpretation indicates enhanced local symmetry breaking consistent with increased defect activity, supporting vacancy related disorder that can facilitate ionic/electrical transport and influence sintering kinetics and grain boundary pathways. The optical band gap study reflects the existing wide band gap in these BZO based ceramics.

**Conclusion:** Dy/Sm co doping retains the cubic phase of $BaZrO_3$ while introducing controlled lattice distortion and vacancy linked disorder. These structural signatures form an admissible criterion for improved transport and densification behaviour, aligning the material system with high temperature electronic device applications.

**Keywords:** ***Rare earth co doping, lattice distortion, vibrational modes, band gap, tuning of transport property***

# PP-30: Tailoring the Properties of Barium zirconate ceramic through Rare-earth Doping: Structural and optical studies

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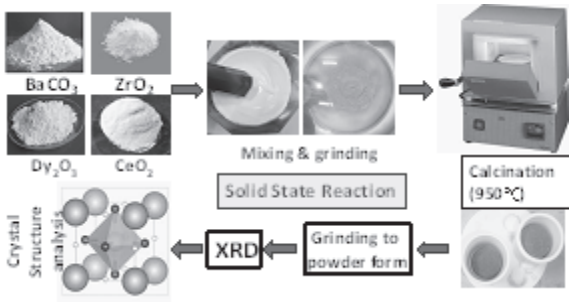
**Introduction:** $BaZrO_3$ is a chemically inert $ABO_3$ perovskite suited to harsh environment humidity/gas sensors and protonic electrochemical components due to its chemical durability. Yet undoped $BaZrO_3$ can be difficult to densify and often exhibits limited mobile carriers, reducing impedance based response. Rare earth co doping is therefore used to tune lattice strain and defect chemistry. Dy perturbs the A site of $BaZrO_3$ and Ce's $Ce^{3+}/Ce^{4+}$ redox flexibility enables competing substitution and compensation, potentially producing oxygen vacancies and mixed ionic-electronic transport. Oxygen vacancies provide sites for hydroxyl/protonic defects and these vacancy mediated pathways directly modulate impedance/resistance, core transduction modes of high temperature ceramic sensors.




**Graphical abstract**

**Materials and Methods:** Dy and Ce were introduced into $Ba^{2+}$ site of $BaZrO_3$ via conventional solid state reaction (mixing, calcination, pressing, sintering). XRD verified phase and symmetry and tracked qualitative lattice parameter shifts from peak positions. Raman spectroscopy complemented XRD by probing disorder and defect sensitive vibrational features linked to oxygen non stoichiometry. UV-Vis analysis provided information regarding the optical band gap of Dy/Ce co-doped $BaZrO_3$ ceramics.

**Results and Discussion:** XRD shows only cubic perovskite reflections for undoped and co doped samples, with no detectable secondary oxides, indicating phase purity and dopant incorporation. Co doped compositions display subtle, non monotonic peak shifts and minor intensity redistribution, consistent with dopant driven lattice distortion and $Ce^{3+}/Ce^{4+}$ enabled multi site compensation. Because Ce can exist as $Ce^{3+}$ and $Ce^{4+}$, the observed non monotonic XRD shifts are consistent with competing site occupancy and charge compensation, yielding a coupled set of cation defects and oxygen vacancies that supports mixed ionic-electronic conduction. Raman interpretation indicates enhanced local symmetry breaking consistent with increased defect activity, supporting vacancy related disorder that can facilitate ionic/electrical transport and influence sintering kinetics and grain boundary pathways. The optical band gap study reflects the existing wide band gap in these BZO based ceramics.

**Conclusion:** Dy/Ce co doping preserves the cubic phase of $BaZrO_3$ while introducing controlled lattice distortion and vacancy linked disorder. These structural signatures provide a defensible basis for improved transport and densification behaviour, aligning the material system with high temperature ceramic sensor and electrochemical requirements.

**Keywords:** ***Rare earth co doping, vacancy mediated structure rearrangement, vibrational modes, band gap, high temperature sensors***

# PP-31: LANTHANUM-BASED DOUBLE PEROVSKITE AS AN EFFICIENT ADSORBENT FOR ENVIRONMENTAL REMEDIATION

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**INTRODUCTION:** Industrial wastewater containing toxic by-products and dye effluents generated through chemical reactions such as oxidation and hydrolysis poses significant environmental concerns. Effluents released from industries including paper, textile, leather, plastics, printing, and cosmetics contaminate water bodies, leading to high chemical oxygen demand (COD), reduced light penetration, and consequent carcinogenic and mutagenic effects on plants, humans, and aquatic life. Among these pollutants, organic dyes are particularly problematic because of their resistance to aerobic degradation. Congo red (CR), widely used in paper, printing, leather, plastic, and textile dyeing industries, has the molecular formula C*f* , H, , N† Na, O† S, and a molecular weight of 696.7 g mol{ ¹. The presence of CR in aquatic environments can cause eutrophication and serious health hazards, including somnolence, skin and eye irritation, and respiratory disorders. Various treatment methods—such as adsorption, photodegradation, chemical oxidation, coagulation, electrochemical oxidation, and biological processes—have been explored for dye removal from wastewater. Among these, adsorption has emerged as the most effective and widely adopted technique due to its simplicity, high efficiency, cost-effectiveness, and operational convenience, making it a promising approach for advanced water purification. For this, double perovskite material $La_2NiMnO_6$ has been proven to be one of the best promising materials

**MATERIALS AND METHOD:** The double perovskite $La_2NiMnO_6$ material was synthesized using lanthanum nitrate hexahydrate, nickel nitrate hexahydrate and manganese sulphate monohydrate via hydrothermal technique for 17 hours at 150 p C. The synthesized double perovskite material was characterized using XRD, FESEM, FTIR, STA which confirmed the formation of the compound. XRD confirmed the formation of double perovskite phase, FESEM detected the formation of nanorods and FTIR confirmed the presence of metal-oxide bond. The compound was then used as an adsorbent for the removal of Congo red dye from aqueous media by batch adsorption process.

**RESULT AND DISCUSSION:** In the batch adsorption process different parameters such as adsorbent dose, time, concentration of the solution and the pH was varied. Optimum dose for the removal of the dye from aqueous media was found to be 0.06g at an optimum time of 90 minutes. On varying the concentration of the dye solution from 100 ppm to 250 ppm, different adsorption isotherm was studied such as Langmuir, Freundlich and Elovich model. Out of all these models it was observed that Langmuir was the best fitted model for the adsorption method with adsorption capacity of 60.24 mg/g.

**CONCLUSION:** The $La_2NiMnO_6$ nanoparticles has been successfully synthesized via hydrothermal method. FESEM study revealed the irregular surface morphology of the synthesized nanoparticles. Successful batch adsorption experiments for Congo red were carried with different dosage of adsorbent, time variation, concentration variation and pH, followed by the kinetics and the isotherm study. The mechanism followed pseudo-second order kinetics and the Langmuir adsorption isotherm with maximum adsorption capacity of 60.24 mg/g for CR dye.

# PP-32: Tuning Structural, Optical Band Gap and Dielectric Behavior in Dy³z Doped NiFe, O,, –Ba€ …. Ca€ …. TiO*f* Multiferroic Composites

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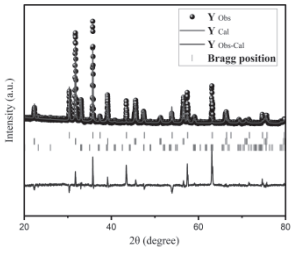
**Introduction:** Recent advancements in multifunctional materials have pivoted toward the development of multiferroic composites that simultaneously exhibit ferroelectric and ferromagnetic properties. Among these, the integration of spinel ferrites and perovskite titanates has emerged as a premier strategy for engineering high-performance magnetoelectric materials. This research focuses on the synthesis and characterization of a composite system comprising Nickel Ferrite ($NiFe_2O_4$) and Barium Calcium Titanate ($Ba_{0.5}Ca_{0.5}TiO_3$), further enhanced through the incorporation of the rare-earth element Dysprosium ($Dy^{3+}$). Nickel ferrite is widely recognized for its high permeability and excellent chemical stability, while Barium Calcium Titanate is prized for its superior dielectric constant and piezoelectric coefficients. By introducing Dysprosium as a dopant, this study aims to exploit the large magnetic moment and 4f-electronic transitions of rare-earth ions to further tune the structural, magnetic, and dielectric properties of the composite. The interaction between the piezomagnetic spinel phase and the piezoelectric perovskite phase is expected to yield a synergistic magnetoelectric effect.

**Methodology:** The composite system (1+x)(NiFe, O,, + Ba€ …. Ca€ …. TiO*f* )xDy, O*f* (x = 0, 0.2, 0.5) was synthesized using the solid-state reaction method. Stoichiometric amounts of high-purity oxide and carbonate precursors were thoroughly ground (2 h dry and 2 h wet milling with methanol) to ensure homogeneity. The mixed powders were calcined at 900 °C for 4 h at a heating rate of 10 °C/min to promote phase formation and remove volatile by-products. Pellets were prepared using PVA as a binder and compacted under 50 kg/cm² using a hydraulic press. The green pellets were sintered at 950 °C for 4 h (10 °C/min).

**Result and Analysis:** The XRD pattern of the x = 0 sample confirms the coexistence of cubic NiFe, O,, and perovskite Ba€ …. Ca€ …. TiO*f* phases without detectable impurities. Good agreement between observed and calculated profiles indicates successful phase formation and high crystallinity. For x = 0.2 and 0.5, slight peak shifts and mild broadening suggest Dy³z incorporation, inducing lattice distortion while preserving the primary crystal structure. UV–Vis analysis reveals a gradual decrease in optical band gap from 2.48 eV (x = 0) to 2.46 eV (x = 0.2) and 2.45 eV (x = 0.5). The band gap values were estimated using Tauc plots, indicating a direct allowed transition. The slight narrowing of the band gap with increasing Dy content may be attributed to defect-induced localized states and lattice strain effects. The dielectric properties of the samples exhibit typical frequency-dependent behavior of ferrite–perovskite composites. Variation in Dy content influences the dielectric response by modifying grain boundary resistance, defect concentration, and charge hopping mechanisms, thereby affecting overall polarization behavior.




**Conclusion:** **Dy³z -**modified NiFe, O,, –Ba€ …. Ca€ …. TiO*f* composites were successfully synthesized using the solid-state reaction method. XRD analysis confirmed phase purity and structural stability with slight lattice distortion upon Dy incorporation. The optical band gap decreased gradually from 2.48 to 2.45 eV with increasing Dy content, indicating enhanced visible-light absorption. Dielectric studies revealed typical frequency-dependent behavior governed by interfacial polarization effects. Overall, Dy addition effectively tunes the structural, optical, and dielectric properties of the composite system.

**Keywords:** ***Spinel Ferrites, Rietveld analysis, Magnetoelectric effect, Piezoelectricity***

# PP-33: Re- Examining Mother-Daughter Relationship: A New Perspective on Feminism in Avni Doshi's *Burnt Sugar*

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**Introduction**: Postmodern feminist writers who raise their voice for rendering social, economic, and political status to women on equal footing with men, focus on intimate and complex relationship with the objective of exposing the trauma faced by a daughter and make her relationship with her mother bitter and harsh. Avni Doshi's novel Burnt Sugar, shortlisted for the Booker Prize in 2020, introduces a new perspective on feminism by deconstructing the mother-daughter relationship. The narrative employs stark realism to portray the silent suffering experienced by a daughter as she cares for her ailing mother, who is suffering from Alzheimer's disease .

**Methodology**: The study includes close reading and textual analysis. This paper applies different theoretical frameworks. Maternal ambivalence theory and feminism theory are employed to shape the interpretation.

**Discussion**: The mother-daughter relationship is often identified as more harmonious than other familial bonds. Doshi challenges this assumption through the metaphorical title "Burnt Sugar," suggesting that even the most cherished relationships can be irreparably damaged. The commonly held belief that "A mother is incomparable" is interrogated as illness and self-absorbed attitude disrupt familial harmony and complicate daily life.

**Conclusion :** Feminism illuminates a hard reality that lies in the life of women, rendering through artistic and literary expression that common readers can not feel. Education, women's empowerment, and financial independence of women could not protect them from such problems. All the rules and regulations meant to protect women are proven inadequate in practice.The above parameters are insufficient to protect women from such forms of harm. Although laws and policies exist to ensure women's safety, they frequently fail to offer effective protection. As a result, women continue to endure emotional and psychological distress within oppressive relationships.

This paper analyses familiar issues through an unconventional lens, thereby presenting a new perspective on feminism.

**Keywords** : Mother-daughter relationship, Feminism, Illness , Post-modernism

# PP-34: Design and Molecular Docking Study of Pyrrolo-[2,3-d]pyrimidine Derivatives as Inhibitors for 1M17 Protein in Cancer Treatment

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**Introduction:** Cancer treatment requires the development of new drugs that can effectively block specific proteins involved in tumor growth. The pyrrolo-[2,3-d]pyrimidine structure is a very important "building block" in medicinal chemistry because it is shaped similarly to the natural molecules our bodies use for energy and signaling. This study focuses on using computer-based methods to test several derivatives (modified versions) of pyrrolo-[2,3-d]pyrimidine as ligands. By targeting the 1M17 protein, which is a key part of the Epidermal Growth Factor Receptor (EGFR) often found in cancer, this research aims to find new ways to stop cancer cell signals.

**Methods and Material:** The research uses computational chemistry and molecular docking to study how well these ligands bind to the protein. First, the 3D structure of the 1M17 protein was taken from the Protein Data Bank (PDB). The protein was prepared by removing extra water and adding hydrogens. The ligand structures were built and their energy was balanced (minimized) to make them realistic. Molecular docking was then performed to see how the ligands "fit" into the active site of the 1M17 protein. We measured the binding energy and looked at the hydrogen bonds and other connections formed between the ligand and the protein.

**Results and Discussion:** The docking results show that several pyrrolo-[2,3-d]pyrimidine derivatives have strong binding scores, meaning they fit tightly into the 1M17 protein. The analysis shows that the core part of our molecules forms important hydrogen bonds with the protein, specifically at the "hinge region" (at the Met769 amino acid). This is significant because it shows our molecules can successfully block the site where the protein usually gets its energy. By changing different parts of the pyrrolo-[2,3-d]pyrimidine scaffold, we were able to find versions that bind even more strongly than some existing drugs.

**Conclusion:** This study shows that pyrrolo-[2,3-d]pyrimidine derivatives are very effective at targeting and inhibiting the 1M17 protein. The computer models provide a clear map of how these molecules work, making the drug discovery process faster and more accurate. These results suggest that these derivatives are strong candidates for further testing and could eventually lead to better cancer treatments.

**Keywords:** ***Pyrrolo-[2,3-d]pyrimidine, Molecular Docking, 1M17 Protein, Cancer Treatment, Ligand, Computational Chemistry.***

# PP-35: Understanding the Effect of Steroidal Surfactants on the Structure and Properties of Lysozyme

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**Introduction:** Protein–surfactant interactions have been studied for over a century due to their importance in diverse fields such as pharmaceutics, drug delivery, food science, biotechnology, and biosciences. Surfactants are known to influence protein structure, sometimes leading to protein unfolding and aggregation, phenomena that are closely associated with several neurodegenerative diseases. Among different classes of surfactants, steroidal surfactants such as bile salts and zwitterionic detergents like CHAPS are of particular interest because of their biological relevance. In this study, we investigate the effect of bile salts and CHAPS on the structural stability and aggregation behavior of lysozyme, a widely used model protein.

**Materials and Methods:** The interaction of lysozyme with bile salts and CHAPS was examined using absorption and fluorescence spectroscopy to monitor structural changes and aggregation behavior. Turbidity measurements and Thioflavin T (ThT) fluorescence assays were employed to confirm the formation of protein aggregates. Additionally, the effect of CHAPS on bile salt–induced aggregation of lysozyme was studied at different CHAPS-to-bile salt ratios to understand the modulatory role of CHAPS.

**Results and Discussion:** Spectroscopic studies revealed that lysozyme undergoes aggregation in the presence of moderate concentrations of bile salts. In contrast, CHAPS alone does not significantly induce aggregation of lysozyme, although it alters the secondary structure of the protein. Turbidity measurements and ThT assay results further support the aggregation behavior of lysozyme under specific conditions. Interestingly, when CHAPS is added to bile salt–induced lysozyme systems, it effectively inhibits aggregation. This inhibitory effect is observed at significantly lower concentrations of CHAPS compared to bile salts, indicating a strong protective role of CHAPS against bile salt–induced protein aggregation.

**Conclusion:** The present study demonstrates that bile salts promote aggregation of lysozyme, whereas CHAPS exhibits a stabilizing effect on the protein structure and suppresses aggregation. Moreover, CHAPS effectively hinders bile salt–induced lysozyme aggregation at relatively low concentrations. These findings provide valuable insights into the role of steroidal surfactants in protein aggregation and may contribute to a better understanding of surfactant-mediated protein stability in biological and pharmaceutical systems.

**Keywords:** Lysozyme, Surfactants, Spectroscopy, Aggregation

# PP-36: Effect of Orthoferrite Substitution on the Structural, Optical, and Dielectric Properties of Spinel Ferrites

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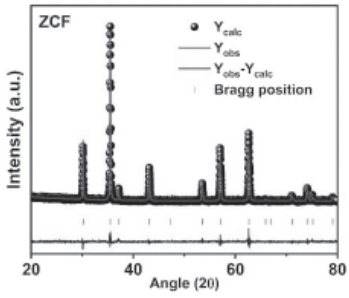
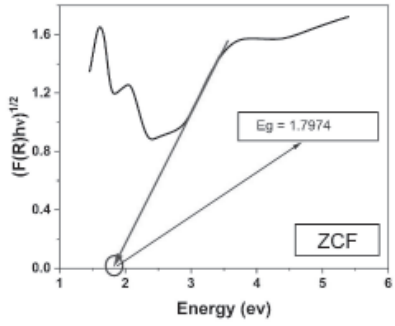
**Introduction:** This manuscript explores the structural, optical and dielectric characteristics of two distinct classes of iron-based oxides—spinel ferrites and ortho ferrites. Incorporation of $DyFeO_3$ into $Zn_{0.5}Co_{0.5}Fe_2O_4$ (ZCF) matrices is an effective strategy to tailor their structural, optical, and dielectric properties. Due to their comparatively large size, $Dy^3z$ ions preferentially occupy the octahedral (B) sites, causing redistribution of $Fe^3z$ ions between tetrahedral (A) and octahedral (B) sites of spinel ferrite ($AB_2O_4$). The structural distortion and rare-earth incorporation affect the dielectric behavior and optical band gap through changes in charge carrier hopping and electronic structure.

**Methodology:** A series of composite samples with the composition (1–x) $Zn_{0.5}Co_{0.5}Fe_2O_4$ – x $DyFeO_3$ (x = 0, 0.04, and 0.08) were synthesized using the conventional solid-state reaction method. All samples were calcined at 1000 °C and subsequently sintered at 1100 °C to achieve the desired phase formation and densification.




**Result and Analysis:** Rietveld refinement of the X-ray diffraction patterns confirms that the undoped sample (x = 0) crystallizes in a single-phase cubic spinel structure with space group Fd–3m corresponding to $Zn_{0.5}Co_{0.5}Fe_2O_4$. In contrast, the composite compositions (x = 0.04 and 0.08) exhibit a biphasic nature, consisting of spinel $Zn_{0.5}Co_{0.5}Fe_2O_4$ and perovskite $DyFeO_3$ phases. The variation in band gap with composition is attributed to changes in the degeneracy of the doping level and the associated modification of the electronic structure. The frequency-dependent dielectric constant (åc") follows the Maxwell–Wagner interfacial polarization mechanism, consistent with Koop's phenomenological theory. Moreover, the temperature-dependent dielectric loss analysis reveals that moderate Er–Fe substitution significantly reduces dielectric loss.




**Conclusion:** The presence of $DyFeO_3$ in the spinel ferrite matrix offers a versatile and effective route for tailoring structural, dielectric, insulating, and optical properties. These tunable characteristics highlight the potential of the developed composites for advanced capacitors, actuators, optoelectronic systems, and other multifunctional device applications.

**Keywords:** X-ray Diffraction; Diffuse reflectance spectroscopy; Dielectric parameters

# PP-37: Lithium Doped Zinc Oxide nanorods: a promising strategy for environmental remediation

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**Introduction:** Clean water is essential for human society, yet industrial discharge and pollution introduce hazardous contaminants into aquatic systems. Photocatalysis has emerged as a simple, cost-effective, and environmentally friendly strategy for wastewater treatment. Several metal oxides, including ZnO, TiO, , and Fe, O*f* , have been explored for dye degradation, with ZnO recognized as one of the most efficient catalysts. Lithium doping further tailors its electronic properties, expanding its potential in photocatalysis. In this work lithium is doped in ZnO and rapid degradation of a dye Malachite Green (MG) is seen. The significant catalytic behaviour of Li-doped ZnO nanorods (NRs) presents a promising opportunity for wastewater treatment and various photocatalytic applications.

**Methods and Material:** The materials used in the synthesis are Zinc nitrate hydrate ($Zn(NO_3)_2.6\ H_2O$) and HMT ($(CH_2)_6N_4$), Lithium Chloride ($LiCl_2.H_2O$), acetone, ethanol, and deionized (DI) water. The samples are synthesized using a simple and cost effective hydrothermal self-assembling technique. Characterization was performed using XRD, SEM, Raman, UV–Vis spectroscopy. Finally the catalytic activity of Li-doped ZnO nanorods was evaluated via degradation of Malachite Green.

**Results and Discussion:** From XRD we find that the ZnO and Li-doped ZnO NRs exhibits crystalline nature and possess a wurtzite hexagonal structure. The XRD pattern (30°–80° range) shows that the diffraction peaks indicate a similar structure to bare ZnO suggesting that Li doping doesn't alter the crystal structure significantly. The XRD confirms successful doping of Li into ZnO without any secondary phases. The SEM demonstrated that the synthesized NRs were dense and randomly grew on the Si substrate with lengths more than microns and diameter approximately 60 to 100 nm respectively. Optical properties of these NRs show that Li doping creates defect states in ZnO nanorods which is responsible for enhanced catalytic activity. Finally the catalytic activity of Li-doped ZnO nanorods was evaluated via degradation of Malachite Green. The NRs achieved ~80% degradation within the 1st 30 minutes, demonstrating a strong catalytic efficiency.

**Conclusion:** The ZnO and Li doped ZnO NRs have been synthesized using hydrothermal technique and studied for their catalytic activity by using MG dye for environmental issues. The XRD study confirms that all samples are hexagonal wurtzite structure. The SEM analysis exhibits the NRs morphology for all the samples and no deviation in the morphology is found due to Li doping. The dye degradation is found to be very fast and efficient. Li doped ZnO NRs can be considered as fast photocatalytic material for the removal of MG dye from industrial wastewater under sunlight radiation and can be considered as an important material for the environmental applications.

**Key Words:** Catalytic, Hydrothermal growth, ZnO, Li-doping

# PP-38: Development of Novel 2D- á-$Bi_2O_3$ Nano-adsorbent for Removal of Organic Pollutant from Polluted Water

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**Introduction:** An intermittent discharge of contaminated effluents to water bodies from industries like textile, mining, printing *etc.*, possess a severe threat to human health and aquatic ecosystems. Out of all available treatment strategies, adsorption using nanostructured materials has emerged as an efficient, cost-effective, and environmentally benign approach. In this study, two-dimensional (2D) $Bi_2O_3$ nanosheets were synthesized and explored as a novel nanoadsorbent for the removal of potential pollutants *i.e.* dyes like Methylene Blue (MB), Eriochrome Black T (EBT) *etc.*, from sample solutions.

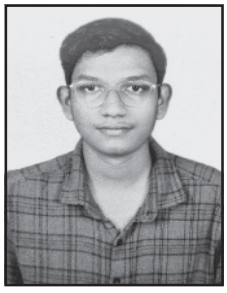
**Materials and Methods:** $Bi_2O_3$ nanosheets were synthesised using sol-gel method. For a standard synthesis 10mmol of Bi(NO*f* )$_3$·5H, O was dissolved in 20mL of ethylene glycol maintaining pH=3. The solution was stirred at 80°C for 1 hour and the sol was dried at 100°C overnight. The obtained whitish gel was calcined at 550°C for 1hour to achieve $Bi_2O_3$ nanomaterials.

**Result and Discussion:** X-ray diffraction (XRD) analysis confirmed the formation of monoclinic á-$Bi_2O_3$ with a space group of P121/c1. The average crystallite size of the synthesized Bi, O*f* nanosheets was found to be ~59.8 nm and lattice parameters found to be $a$ = 5.73 Å, $b$ = 8.17 Å, and $c$ = 7.62 Å. FTIR analysis reveals a characteristic Bi–O–Bi stretching vibration at 840 cm{ ¹, while absorption bands observed at 637 cm{ ¹ and 480 cm{ ¹ correspond to Bi–O bonds, confirming the successful formation of $Bi_2O_3$. Morphological analysis (FESEM) confirmed a well-defined nanosheet-like two-dimensional structure. Investigation of optical properties confirms that á-$Bi_2O_3$ is a wide band-gap semiconductor material with $E_g$ = 2.71 eV. The adsorption efficiency of $Bi_2O_3$ nano adsorbents were evaluated through batch experiments using potent dye effluents like methylene blue (MB) and Eriochrome Black T (EBT) by varying factors like dye concentration, adsorbent dosage, temperature, contact time, and pH. Adsorption kinetics, isotherm behavior, and thermodynamic parameters were also investigated to apprehend to establish a detailed mechanism. Thermodynamic results indicated that the adsorption process was spontaneous and exothermic. Kinetics analysis showed that the pseudo-second-order model best described the adsorption behavior ($R^2$ = 0.973). Additionally, the Freundlich isotherm model ($R^2$ = 0.996) provided a better fit to the experimental data, suggesting heterogeneous surface adsorption. The maximum adsorption capacity and removal efficiency were determined to be 66.5 mg/g and 88%, for MB and 42.2 mg/g and 76% for EBT respectively.

**Conclusion:** An optimized facile and economical approach for synthesis of 2D á-$Bi_2O_3$ nanosheets was developed. The physico-chemical characterization (*i.e.* XRD, FESEM, UV-Vis, PL, Raman, FTIR, BET, Zeta potential etc.) confirms the formation of monoclinic á-$Bi_2O_3$ phase pure wide bandgap semiconductor nano-adsorbent. Adsorption batch experiments using potent effluent dyes (MB, EBT) demonstrates high adsorption capacity, rapid adsorption kinetics and reusability for effective removal highlights the potential of 2D $Bi_2O_3$ nanosheets as a promising adsorbent for wastewater treatment applications.

**Keywords:** Two dimensional; Bi, O*f* nanosheets; Nano-adsorbent; Organic dye; Adsorption; Wastewater treatment

# PP-39: Topological insulator: A New Phase of Matter



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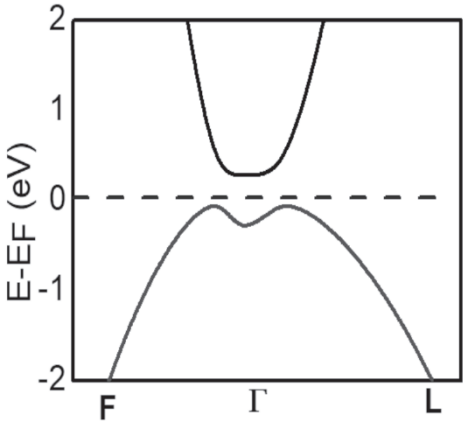
**Introduction:** Topological insulators, a class of quantum materials that represent exotic behaviour. These novel materials show significant interest in both theoretical and experimental condensed matter physics. One instance being they show electrical insulating behaviour at their interior, but show metallic behaviour at the edges. In this work, comprehensive studies were carried out on $Bi_2Se_3$ and related materials to evaluate their electronic properties.

**Methods and Materials:** The tight-binding method is used for the evaluation of electronic structures. A specific discrete lattice Hamiltonian is considered with the incorporation of spin-orbit coupling. Parametrization of hopping integrals was carried out by choosing suitable orbitals. $Bi_2Se_3$ is considered as the standard topological material, and calculations were extended for related materials.

**Results and Discussion:** The simulation results show the band structure of $Bi_2Se_3$. It shows a band inversion at the **Ã** point (unlike the Dirac cones for graphene). The asymmetry of the Dirac hyperbola is revealed for the valence band. It is attributed to the asymmetry of hole mobility around the **Ã** point. The preferential hole mobility affects the differential in charge carrier behaviour, making them special. However, the electron mobility is roughly the same around the **Ã** point as observed from the conduction band. This discrepancy in the charge carrier mobility adds to the complexity in the electronic structure of topological materials. These properties can show integral/fractional charge transport in special devices like the quantum hall effect.




**Conclusion:** Our studies on topological insulating materials, based on the tight-binding method, show exotic behaviour of the quantum materials. Our approach can be extended to explore more topological materials for special electronic devices.

**Keyword:** *Topological Insulator, Tight-Binding, $Bi_2Se_3$, Dirac Hyperbola.*

# PP-40: Biogenic synthesized $CaCO_3$ nanoparticles: Assessing dye degradation potential, phytotoxicity and antibacterial textile application

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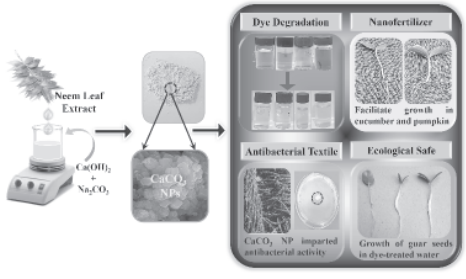
**Introduction:** The textile industry has seen an unprecedented boom in recent years and the textile industries are heavily dependent on dyes, which subsequently pave the path for the generation of wastewater effluent. The textile dyes are highly stable, aqueous soluble, and non-biodegradable. The ingestion or inhalation of these dyes has triggered respiratory/ skin infections, eye irritations and other maladies. In current times, an economical, ecologically safe, antimicrobial and reusable catalyst for environmental remediation is warranted. The utilization of green synthesized nanoparticles (NPs) has drawn attention as it is environmentally benign. The investigation of calcium carbonate NPs as photocatalysts for dye degradation is an interesting topic.

**Materials and Methods:** Fresh neem leaves were plucked from trees in OUTR campus, Bhubaneswar, Odisha. $Ca(OH)_2$ solution was added drop-wise to $Na_2CO_3$ solution. Neem extract was added to the aforesaid solution mixture and stirred at 60 °C for 3 h. The precipitate was oven-dried at 80 °C, which yielded the $CaCO_3$ NPs. Different analytical techniques such as UV-Vis, FTIR, XRD and FESEM were performed. Dye degradation studies and antibacterial analyses were carried out.

**Results and Discussion:** Green synthesis of the NPs was accomplished from *A. indica* leaf extract. The formation of $CaCO_3$ NPs was affirmed from UV–Vis spectroscopy by detecting the characteristic ëmax, a broad absorption band was noted in the range of 250–400 nm, which confirmed the synthesis of NPs. The XRD profile and FESEM image of the $CaCO_3$ NPs revealed the calcite phase of $CaCO_3$ polymorph with an average particle size of 75.25 nm. A band gap of 2.99 eV was estimated for the NPs from the Tauc plot. Photocatalytic efficacy of $CaCO_3$ NPs was investigated for methyl orange, crystal violet and methylene blue and their ternary mixture under sunlight. The NPs showed excellent photocatalytic efficiency in terms of dye degradation percentage and stability till the fourth cycle. $CaCO_3$ NPs-coated cotton fabric showed good antibacterial activity against *E. faecalis*. $CaCO_3$ NPs displayed good efficacy as a nanofertilizer for cucumber and pumpkin seeds.

**Conclusion:** Green synthesis of $CaCO_3$ NPs was accomplished via Neem leaf extract. The obtained CaCO3 NPs were characterized by different analytical techniques. A band gap energy of 2.99 eV was estimated using the Tauc method. The NPS depicted good photocatalytic dye degradation efficiency for hazardous textile dyes. The $CaCO_3$ NPs-coated cotton fabric displayed remarkable antibacterial efficacy against a common pathogenic bacterial strain, *E. faecalis*. Furthermore, the ecotoxicological assay indicated no inhibitory phytotoxicity on guar seedlings.

**Keywords:** Nano $CaCO_3$, Green synthesis, Photocatalytic activity, Phytotoxicity, Antibacterial textiles



# PP-41: Literary Ecologies and Lived Experience: A Reading of The Fanged Waters

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**Abstract**

The symbolic representation of rivers in literature discusses their active roles in *constructing* a society, history and geography of a particular territory and simultaneously influence the people involved.These narratives of river display the intricacies of ecology, history, and human consciousness. This work represents the dichotomy of rivers through the novel "*The Fanged Waters*" which is a translated version by Dr. Snehaprava Das from original Odia novel "Badhi Paanira Daanta"written by Prasanna Kumar Mishra. This novel reflects how the river Baitarani being regarded as a serene entity, a lifeline and a joyful source for the children of the village became monstrous by devouring the protagonist's father and leaving her fate in to an uncertainty. The book establishes an eco-critical approach by revealing the duality of nature as the warm bosom of the river turns to scourge during monsoons when the habitats and the plains get flooded in the low lying areas near the course of the river which was highly fertile by creating a fortune for the livelihood of the villagers.

**Methodology**

The primary method of textual analysis involves a close reading of the narrative strategies, imagery, characterization, and symbolism in the selected fiction to explore how ecological and socio-political themes are embedded in the text. The literary analysis will also integrate historical and ecological data pertaining to the rivers for the fictional representations.

**Discussion**

The research will generate an approach of understanding the river fictions from a literal sense building a connection between literature and ecology where the scholars as well as the readers would be aware of their responsibility towards the conservation and protection of the river bodies which carry an utmost importance in Indian society.

**Conclusion**

River narrative has become an emerging discipline in the field of literary research by influencing the researchers to understand the importance of river images as portrayed in literature. It would also highlight the responsibilities of a civilized society to respect and restore the sanctity and purity of the water bodies amidst the anthropogenic developments.

**Keyword: Eco-Criticism, River Narratives.**

# OP-42: A Novel Metaheuristic Approach to VM Consolidation: Hedgehog Hibernation Optimization for Cloud Computing

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**Introduction:** Cloud computing's rapid expansion created substantial energy consumption challenges, with data centers consuming approximately 1% of global electricity. *Problem:* Server utilization mismatches power consumption-overutilized servers risk SLA violations while underutilized machines consume substantial energy with minimal computational contribution. Traditional resource allocation methods (Best Fit Decreasing, ACO, PSO) demonstrate limited effectiveness, struggling with scalability and adaptability in dynamic virtualized environments. *Research Gap:* Existing consolidation algorithms operate in binary paradigm, either prioritizing energy conservation at SLA expense or maintaining performance through excessive migration overhead, lacking integrated selective migration with adaptive hibernation mechanisms. *Motivation:* Hedgehog hibernation behaviors inspire optimal balance between VM consolidation and SLA compliance. This work proposes Hedgehog Hibernation Optimization (HHO) algorithm for energy-aware cloud resource management.

**Materials and Methods:** System model comprises heterogeneous physical hosts with linear power consumption: P(u) = P_idle + (P_max - P_idle)·u. VMs characterized by time-varying CPU, memory, storage demands. SLA compliance: Ó(demand - allocated)/Ódemand d" threshold. HHO monitors host utilization, categorizing into overloaded (>80%), underloaded (<30%), or balanced states. Overloaded hosts trigger selective VM migration via: min Ó(migration_cost) subject to utilization reduction. Underloaded hosts undergo VM evacuation followed by hibernation. CloudSim simulation with 50-100 heterogeneous hosts (10,000-20,000 MIPS, 32-64 GB RAM), 200-400 VMs, PlanetLab workload traces over 7 days. Compared against ACO, PSO, MBFD. Metrics: energy consumption (kWh), SLA violation percentage, VM migration frequency.

**Results and Discussion:** (1) Energy consumption: HHO averaged 119.3 kWh versus ACO (135.3 kWh), PSO (140.4 kWh), MBFD (149.6 kWh), achieving 11-20% reductions through intelligent hibernation eliminating idle power; (2) SLA violations: HHO 0.86% versus ACO (1.42%), PSO (1.68%), MBFD (2.16%), demonstrating 40-60% improvements confirming energy conservation doesn't compromise service quality; (3) VM migrations: HHO averaged 254 versus ACO (289), PSO (313), MBFD (377), achieving 12-33% reductions indicating superior operational stability; (4) Migration duration: HHO 35.2 seconds versus ACO (42.7s), PSO (46.2s), MBFD (38.9s), improvements of 17.6-23.8%; (5) Data transfer: HHO 1866 MB versus ACO (2162 MB), PSO (2396 MB), MBFD (2800 MB), reductions of 13.7-33.4%. Biologically-inspired hibernation mechanisms enable aggressive power optimization without service degradation.

**Conclusion:** HHO successfully addresses cloud resource management trade-offs, demonstrating consistent performance across realistic workloads. The algorithm's selective migration strategy combined with intelligent hibernation achieves superior multi-dimensional optimization, positioning it as a viable solution for sustainable cloud operations. Future work includes production deployment validation, hybrid optimization frameworks, and expanded objectives incorporating carbon footprint and renewable energy integration.

**Keywords:** Cloud Computing, Energy Efficiency, Green Cloud Computing, Hedgehog Hibernation Optimization, Virtual Machine Consolidation

# OP-43: Enhanced Multi-Cancer Diagnosis using a Fine-Tuned Transformer-VGG19 Approach

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**Introduction:** Cancer is one of the leading global health challenges, accounting for millions of deaths annually due to delayed diagnosis and limited accessibility to advanced diagnostic systems. Early and accurate detection of cancer significantly improves survival rates and treatment effectiveness. The primary objective of this study was to develop a robust deep learning–based framework for multi-cancer detection, specifically targeting brain, breast, and lung cancers, using clinically validated MRI datasets.

**Materials and Methods**: The study utilized a real-time MRI dataset collected from Capital Hospital, Bhubaneswar, India, ensuring clinical authenticity and patient diversity. To address the limitation of a small dataset, a comprehensive preprocessing pipeline was implemented, including image enhancement and MedGAN-based data augmentation to increase variability and improve generalization. A deep learning model based on VGG-19 was employed for feature extraction, integrated with transformer modules to capture contextual and spatial representations effectively. The extracted deep features were further optimized using an Adaptive Genetic Algorithm (AGA) to enhance classification accuracy, minimize prediction error, and ensure convergence stability. The framework was evaluated using 9-fold cross-validation along with an additional 5% external dataset testing to assess robustness and generalizability. Performance metrics including accuracy, precision, recall, and F1-score were computed for evaluation.

**Results and Discussion**: The proposed framework achieved an accuracy of 98.7 ± 0.34%, with a precision of 0.973, recall of 0.967, and F1-score of 0.981, demonstrating high reliability in multi-cancer detection. The integration of VGG-19 with transformer modules enabled effective extraction of discriminative spatial and contextual features from MRI scans. The Adaptive Genetic Algorithm significantly improved feature selection and optimization, contributing to reduced misclassification and enhanced convergence stability. The 9-fold cross-validation and external dataset testing confirmed strong generalization capability across diverse patient samples. Grad-CAM visualization was applied to enhance interpretability, providing clinically meaningful insights into the model's decision-making process by highlighting relevant tumor regions. Comparative analysis indicated that the hybrid framework outperformed conventional deep learning approaches in both accuracy and robustness. The model demonstrated resilience to variations in image quality and patient demographics, reinforcing its suitability for real-world clinical deployment.

**Conclusion/Recommendation:** The proposed deep learning framework integrating VGG-19, transformer modules, and Adaptive Genetic Algorithm demonstrated excellent performance for multi-cancer detection. Future work may focus on expanding the dataset across multiple institutions, incorporating multimodal imaging data, and exploring advanced ensemble or federated learning techniques to further enhance scalability, robustness, and clinical applicability.

**Keywords**: Multi-Cancer Imaging, MedGAN, Data Augmentation, Feature Extraction, Transfer Learning, Deep Learning, AGA and K-fold validation.

# OP-44: Cloud–AI Digital Twin Framework for Decision-Intelligent Resilience of Marine Infrastructure

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**Introduction:** Marine infrastructure such as ports, offshore platforms, and coastal installations faces dynamic environmental stress, structural fatigue, and extreme weather events, leading to high maintenance costs and failure risks. *Problem:* Conventional marine monitoring is reactive, relying on periodic inspections or threshold-based alarms that provide limited situational awareness and delayed response, causing costly failures. *Research Gap:* While IoT sensing and machine learning prediction exist independently, no framework integrates cloud-hosted digital twins with AI-driven decision intelligence for marine infrastructure, lacking continuous synchronization and resilience-oriented decision strategies. *Motivation:* Integrating digital twins with cloud and AI enables proactive resilience management through continuous sensor fusion, scalable analytics, and decision intelligence. This work proposes a cloud-hosted, AI-driven digital twin framework for intelligent marine infrastructure resilience.

**Materials and Methods:** Layered architecture: (1) Physical layer with sensors measuring structural stress, vibration, corrosion, tidal variations, meteorological conditions; (2) Edge gateways for preprocessing and secure forwarding; (3) Cloud layer with scalable data ingestion, digital twin engine, AI analytics; (4) Digital twin maintaining virtual representation synchronized with real-time inputs, incorporating environmental factors. AI analytics perform anomaly detection and failure risk estimation via: Risk = f(Stress, Environmental Load, Vulnerability). Decision intelligence generates prioritized alerts using risk-aware strategy. Evaluation uses realistic marine scenarios comparing baselines: Conventional Monitoring (CM), Sensor + Threshold Alerting (STA), Cloud-Based Monitoring (CBM), Cloud + ML Prediction (CML). Metrics: alert precision/recall, response latency, maintenance cost reduction, energy consumption.

**Results and Discussion:** (1) Alert precision H" 0.93 and recall H" 0.92, significantly outperforming baselines-CM had low precision/recall, STA suffered excessive false positives, CML improved but lacked system-level modeling; (2) Confusion matrix showed strong true positives/negatives with minimal false alarms versus dense false-positive region in STA; (3) Response latency <3 units at peak workload while CM, CBM, CML exhibited near-linear growth exceeding acceptable times; (4) Maintenance cost reduction H" 55% versus CML (H"38%) and CBM (H"20%) through accurate prioritization; (5) Energy consumption notably lower than CML as decision intelligence reduces redundant processing. System-level integration of digital twin with AI-based risk inference delivers superior alert quality, faster response, and meaningful cost savings.

**Conclusion:** This cloud–AI digital twin framework demonstrates that integrating continuous synchronization with AI decision intelligence substantially outperforms conventional, cloud-only, and ML-only approaches across all operational metrics. The framework effectively balances alert accuracy, response speed, and resource efficiency, confirming practical viability for large-scale marine deployments. By shifting from data-centric monitoring to decision-oriented intelligence, this work establishes a scalable foundation for sustainable and resilient marine infrastructure management.

**Keywords:** Digital Twin, Marine Infrastructure, Cloud Computing, Artificial Intelligence, Resilience Engineering, Decision Support Systems

# OP-45: A Blockchain-Enabled Supply Chain Management Framework with Consensus-Aware Performance Analysis

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**Introduction:** Supply Chain Management (SCM) is a complex and distributed network involving suppliers, manufacturers, wholesalers, distributors, retailers, and customers. With the rapid digitisation and integration of technologies such as IoT, AI and ML, SCM systems are increasingly vulnerable to security threats, a lack of transparency, and data integrity risks. Traditional centralised supply chain databases often suffer from limited traceability, weak trust mechanisms, and vulnerability to unauthorised modification. Blockchain technology offers a decentralised, tamper-resistant ledger that can strengthen transparency and accountability among supply chain stakeholders. This study proposes a blockchain-enabled SCM framework to securely record transactions, improve traceability, and enhance trust through consensus mechanisms and automated smart contract execution.

**Methods and Material:** The proposed blockchain-based SCM framework models the supply chain as a distributed network of nodes, where each node represents a participant such as a supplier, manufacturer, distributor, retailer, customer, or regulator. Transactions are created for supply chain events containing sender–receiver details, product identifier, quantity, timestamp, and digital signature. Each transaction is validated for authenticity and compliance before being accepted into a transaction pool. Validated transactions are grouped into blocks, and Merkle trees are constructed to generate a Merkle root, ensuring the integrity of transaction data. Blocks contain index, timestamp, Merkle root, previous hash, and nonce for Proof-of-Work (PoW) mining.

**Result and Discussion:** Simulation results demonstrate that blockchain integration improves SCM transparency and traceability by creating immutable records linked through cryptographic hashes. Mining time per block is highest for the first block and lower for subsequent blocks, reflecting initialisation overhead and the probabilistic nature of hashing. Consensus time follows a similar pattern, with faster agreement after the network stabilises. Block propagation results show the delay required for distributing validated blocks across nodes to maintain synchronised ledgers. Comparative analysis indicates that mining time contributes more delay than consensus and propagation time, making PoW the dominant performance factor. Experiments across different PoW difficulty levels reveal that greater difficulty significantly increases mining duration and nonce iterations, highlighting a trade-off between stronger security and operational efficiency.

**Conclusion:** The proposed blockchain-enabled SCM framework enhances trust, transparency, and traceability among geographically dispersed stakeholders by ensuring secure transaction validation and tamper-resistant record keeping. Through cryptographic hashing, Merkle tree integrity, consensus-based block validation, and smart contract automation, the system improves accountability and reduces risks of fraud and data manipulation.

**Keyword:** ***Blockchain, Supply Chain Management, Proof-of-Work, Smart Contract, Merkle Tree, Consensus, Mining Time, Traceability, Transparency, Data Integrity.***

# OP-46: Adaptive Segmentation of Fetal Head Structures in Ultrasound Images Through Multi-Model Deep Learning Approach

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**Introduction:** Accurate measurement of fetal head circumference is essential for prenatal assessment of fetal growth and development. Manual delineation of fetal head boundaries in ultrasound images remains time consuming and subject to inter observer variability among clinicians. Automated segmen- tation techniques using deep learning offer a promising solution to enhance measurement consistency and reduce diagnostic workload. This study investigates the performance of three convolutional neural network architectures for precise fetal head boundary detection in two-dimensional ultrasound scans. The research aims to identify the most effective model configuration for clinical deployment in resource constrained settings while maintaining high segmentation accuracy.

**Materials and Methods:** The study utilized the HC18 Grand Challenge dataset containing 999 fetal ultrasound images with expert annotated masks. Images were resized to 256 by 256 pixels and nor- malized using ImageNet statistics. Three segmentation models were implemented including U Net U Net Plus Plus and DeepLabV3 each employing a ResNet34 encoder pretrained on ImageNet. Train- ing incorporated geometric augmentations and utilized the Dice loss function optimized with the Adam algorithm for five epochs on GPU hardware.

**Results and Discussion:** UnetPlusPlus achieved the highest validation performance with Dice score 0.2243, intersection over union 0.1263 and accuracy 0.9788 at epoch three. Unet attained Dice score 0.2172 and IoU 0.1218 while DeepLabV3 reached Dice score 0.2097 and IoU 0.1172. All models demonstrated consistent training progression with validation accuracy exceeding 97 percent. Visual inspection revealed UnetPlusPlus produced more continuous boundary delineation with fewer segmen- tation gaps particularly around irregular fetal head contours. The nested skip connection architecture likely enhanced feature propagation and boundary preservation. These findings confirm that archi- tectural design significantly influences segmentation quality for medical ultrasound images requiring precise boundary detection.

**Conclusion / Recommendations:** UnetPlusPlus emerged as the optimal architecture for fetal head segmentation, offering the best balance of segmentation accuracy and boundary continuity. The study demonstrates deep learning's potential for automating fetal biometry measurements in ultrasound imag- ing. Future work should evaluate model performance on larger datasets and incorporate test set valida- tion. Implementation in clinical settings requires further optimization for real time processing. These findings provide valuable insights for developing reliable automated tools to support prenatal care and reduce diagnostic workload for healthcare professionals.

**Keyword:** Fetal Head Segmentation, U Net, Deep Learning, Ultrasound Imaging, Medical Image Anal- ysis

# OP-47: A Novel Hybrid AI Framework for Real-Time Cognitive Load Modeling and Mental Health Assessment Using EEG

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**Introduction:** The increase in the frequency of mental health issues in cognitively challenging settings has led to a need to explore complex ways of comprehending the interaction between cognitive load and working memory. The mental burden known as cognitive load is the direct factor that determines memory performance, decision-making and learning outcomes. Yet, traditional methods of analysis usually do not take into account the nonlinear psychological interactions and cannot integrate such critical variables as emotional resilience and ability to think. This paper suggests an artificial intelligence-based framework to analyse these relationships systematically and gain more understanding of cognitive functioning and mental well-being.

**Materials and Methods:** Two stages hybrid framework combining fuzzy logic and machine learning is built with the aid of electroencephalography (EEG)-based cognitive measures. The fuzzy inference mechanisms used in the first stage use emotional resilience and thinking ability to classify cognitive load and are therefore, good in dealing with the uncertainty that is inherent in human cognition. The second level is a model of the combined effect of cognitive load and working memory to be predictive of both cognitive learning and mental health outcomes. EEG recordings were pre-processed, normalized and feature extracted on healthy adult subjects. The predictive strength of the framework was tested with a range of supervised machine learning classifiers, such as Support Vector Machine, Naive Bayes, Decision Tree (J48), and Random Forest which were run with cross-validation methods.

**Results and Discussion:** The experimental study demonstrates that high cognitive load is a significant limitation to the working memory capacity, which leads to cognitive fatigue and the worsening of mental health. On the other hand, increased emotional resilience and better cognitive ability are correlated with better cognitive regulation. Of the considered models, SVM, Decision Tree, and Random Forest showed a better classification performance and achieved around 95 percent accuracy, which proves the worthiness of the suggested architecture. The fuzzy logic in combination with machine learning allows modelling complex cognitive dynamics with high accuracy, which is highly important in comparison to the traditional linear approaches.

**Conclusion:** The hybrid framework proposed is an improvement of the existing paradigms of cognitive assessment in providing a data-driven and scalable method of analysing the relationship between cognitive load, working memory and mental health. This allows it to be an attractive tool in adaptive learning systems, healthcare monitoring, and high-stakes professional environments due to its ability to aid real-time cognitive evaluation.

**Key words**: Cognitive Load (CL), Working Memory (WM), Emotional Resilience (ER), Thinking Ability (TA), Electroencephalography (EEG), Fuzzy Logic

# OP-48: SHA256-Based Route Integrity Verification in Digital Microfluidic Biochips

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**Introduction:** Digital Microfluidic Biochips (DMFBs) enable precise manipulation of tiny droplets on programmable electrode arrays, making them powerful tools for modern diagnostics and lab-on-chip applications. These systems rely on predefined routing sequences to transport droplets accurately across the chip surface. However, as DMFB controllers become digitally connected and software-driven, the routing data becomes vulnerable to manipulation. Even a minor alteration in electrode activation can compromise assay accuracy and produce unreliable medical results. Therefore, ensuring secure and verifiable droplet routing is essential for maintaining the integrity and trustworthiness of DMFB-based diagnostic systems.

**Methods and Material**: Synthetic droplet routing datasets are generated to simulate electrode activation sequences in an 8×8 DMFB grid. Three dataset sizes—100, 500, and 1000 routes—are created to evaluate scalability. Each routing sequence is converted into a string format and authenticated using the SHA256 hashing algorithm. The generated hash value is stored as a digital signature for integrity verification. Tampering and replay attacks are artificially introduced to test system robustness. Performance metrics such as signing time, verification time, and detection rates are recorded and analyzed.

**Result and Discussion**: The performance evaluation shows that signing and verification times increase gradually with dataset size, indicating predictable scalability. Even for 1000 routes, the processing time remains below 0.004 seconds, demonstrating low computational overhead. This confirms that the hash-based mechanism is lightweight and suitable for embedded DMFB controllers. From a security perspective, tamper detection rates range between 43% and 47%, reflecting the simulated attack conditions. Replay attack detection consistently remains at 92% across all datasets, showing stable defensive capability. The slight variation in tamper detection suggests sensitivity to the randomness of injected modifications. Overall, the results indicate that the proposed approach balances security enforcement with minimal performance impact.

**Conclusion:** The study demonstrates that hash-based route authentication can effectively enhance the security of droplet routing in Digital Microfluidic Biochips. Performance analysis confirms that the added security layer introduces minimal computational overhead, even as dataset size increases. The system shows consistent resistance against replay attacks and moderate detection capability under simulated tampering conditions. These findings suggest that lightweight cryptographic mechanisms are feasible for integration into embedded DMFB controllers. For improved robustness, future work may incorporate HMAC or lightweight encryption standards and real-time anomaly detection techniques.

**Keywords**: Digital Microfluidic Biochips (DMFB), Droplet Routing Security, SHA256, Tamper Detection, Replay Attack Detection

# OP-49: Multi-Agent Deep Reinforcement Learning for Pareto-Optimal Task Offloading in Edge-Cloud Computing

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**Introduction:** With the rapid growth of Internet of Things (IoT) applications and latency-sensitive services, efficient task offloading has become critical in edge–cloud computing environments. Therefore, devices with limited computational capability and energy resources often cannot perform computation-intensive tasks locally, necessitating offloading to edge or cloud servers to meet latency and performance requirements. Edge servers provide low-delay processing closer to users, whereas cloud servers offer abundant computational capacity for complex workloads. However, dynamic network conditions, limited edge capacity, and stringent deadline constraints make optimal decision-making challenging. Consequently, an intelligent and adaptive task offloading mechanism is required to efficiently determine whether a task should be processed at the edge or offloaded to the cloud. **To address these limitations, this paper proposes a novel multi-agent deep reinforcement learning framework that jointly minimizes latency and energy consumption while maximizing SLA satisfaction** under edge capacity constraints.

**Methods and Material:** This work considers a multi-agent edge-cloud computing environment consisting of edge devices, an edge server with limited computational capacity, and a remote cloud server with transmission delay. Each task is defined by its task size , required CPU cycles, and deadline. A deep reinforcement learning (DRL)-based task offloading framework is proposed, in which the state space comprises task parameters, available bandwidth, cloud delay, and current edge load. The action space comprises two decisions, such as offloading to the cloud or local edge processing. The offloading problem is formulated as a constrained Pareto multi-objective optimization under edge capacity limitations.

**Result and Discussion:** To evaluate convergence behaviour, simulations were conducted with 10 agents and 20 tasks of varying sizes. The convergence of the proposed multi-agent DRL framework was analyzed with respect to the reward function. The performance metrics, including average latency, average energy consumption, throughput, Jain's Fairness Index, edge utilization, cloud utilization, and SLA violation rate, were evaluated under multiple scenarios, each consisting of varying numbers of agents, task sizes, and deadline constraints. The proposed method was compared with an existing DRL-based approach, greedy strategy, random offloading method, and an Always-Edge based method. The proposed framework outperforms the existing methods by reducing latency and energy consumption while improving SLA satisfaction.

**Conclusion:** The proposed approach addresses dynamic network conditions, limited edge capacity, and stringent deadline requirements through a Pareto multi-objective formulation. The results demonstrate improved latency performance, reduced energy consumption, and greater SLA satisfaction compared with conventional methods.

**Keyword:** ***Edge–Cloud Computing, Task Offloading, Multi-Agent Systems, Deep Reinforcement Learning, Pareto Multi-Objective Optimization, SLA Satisfaction, Latency Optimization, Energy Efficiency***

# OP-50: A Hybrid Deep Learning and Blockchain Framework for Real-Time IoT DDoS Resilience

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Introduction: The exponential growth of Internet of Things (IoT) networks has significantly increased vulnerability to Distributed Denial-of-Service (DDoS) attacks. Resource constrained IoT devices lack robust built in security, making them prime targets for botnet-driven disruptions. Conventional intrusion detection systems often struggle with heterogeneous traffic patterns and centralized logging mechanisms that are susceptible to tampering. Although deep learning enhances detection capability and blockchain ensures data integrity, their unified deployment for IoT resilience remains limited. This study proposes an integrated framework combining hybrid deep learning with blockchain enabled tamper proof logging for real time DDoS defense.

Materials and Methods: The architecture integrates three layers: an IoT network, an edge-based intrusion detection system, and a blockchain layer. The detection engine uses a hybrid CNN-LSTM-Transformer model trained on the TON IoT dataset (25,244 samples). CNN extracts spatial traffic features, LSTM captures temporal dependencies, and Transformer enhances long-range sequence learning. Blockchain is implemented via Solidity smart contracts on a private Ethereum network (Ganache-cli), with IPFS for secure off-chain storage. Core functions—registerNode, storeData, retrieveData, and blacklistNode—enable authenticated device management and immutable logging. Evaluation covers accuracy, precision, recall, F1-score, confusion matrix, latency, gas consumption, and throughput.

Results and Discussion: Experimental results demonstrate 99.01% detection accuracy with precision, recall, and F1-score of 0.990. The confusion matrix indicates minimal false positives and false negatives, confirming balanced classification performance. The ROC curve achieved an AUC close to 1.0, validating robustness across attack scenarios. The blockchain layer successfully handled multiple IoT nodes with low-latency blacklisting (256.88 ms) and throughput of 3.89 TPS. While data storage operations incurred moderate gas costs due to IPFS interaction, retrieval accuracy remained 100%, ensuring integrity and transparency.

Conclusion: The proposed hybrid framework effectively integrates high-accuracy deep learning detection with blockchain based tamper proof auditing for IoT environments. The CNN-LSTM-Transformer model ensures reliable real time DDoS identification, while Ethereum-IPFS integration guarantees immutability and secure access control. The system demonstrates scalability, security, and operational efficiency suitable for smart cities, healthcare, and industrial IoT deployments. Future work will focus on optimizing edge inference speed and enhancing privacy through advanced cryptographic techniques.

Keywords: IoT Cybersecurity, DDoS Detection, Hybrid Deep Learning, Blockchain Security, IPFS, TON IoT Dataset

# OP-51: CPS-AgriFedSecure: Scalable and Secure Federated Learning for Agricultural Cyber–Physical Systems Using Blockchain and HPC

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**Introduction:** Sustainable smart agriculture increasingly relies on data-driven intelligence to support critical applications such as crop yield prediction, disease monitoring, and water-efficient irrigation. However, conventional centralized learning approaches pose serious challenges, including excessive communication overhead, high energy consumption, privacy risks, and vulnerability to single-point failures. These limitations are further exacerbated in rural agricultural environments characterized by heterogeneous devices, non-IID data distributions, and intermittent connectivity. To address these challenges, this work proposes CPS-AgriFedSecure, a secure, decentralized, and scalable federated learning (FL) framework tailored for agricultural cyber–physical systems (CPS).

**Materials and Methods:** CPS-AgriFedSecure enables collaborative model training across geographically distributed farms using locally generated multimodal sensor data, thereby eliminating centralized data collection. The framework integrates a permissioned consortium blockchain with PBFT-based consensus to provide decentralized authentication, immutable logging of model updates, and verifiable aggregation. This design mitigates federated learning–specific threats such as model poisoning, free-riding, and Sybil attacks. To ensure scalability and low latency, high performance computing (HPC)-assisted parallel computation is employed for model aggregation, validation, and anomaly detection. Blockchain operations are restricted to metadata-level on-chain transactions, while bulk model parameters are exchanged and processed off-chain, minimizing communication and energy overhead.

**Results and Discussion:** The proposed framework is designed to operate effectively under non-IID data distributions, heterogeneous computational resources, and unreliable network conditions typical of rural farming environments. Experimental evaluations conducted on representative agricultural analytics tasks, including crop yield prediction, disease classification, and irrigation demand forecasting, demonstrate that CPS-AgriFedSecure achieves competitive predictive accuracy while significantly reducing communication overhead. The integration of HPC-based parallelism improves aggregation efficiency and system scalability, while blockchain-enabled security enhances trust and robustness without incurring excessive computational costs.

**Conclusion:** This study presents CPS-AgriFedSecure as a sustainable, privacy-preserving, and trustworthy federated learning framework for agricultural cyber–physical systems. By combining decentralized learning, blockchain-based security, and HPC-assisted parallel computation, the proposed approach effectively addresses scalability, security, and efficiency challenges in smart agriculture. CPS-AgriFedSecure provides a strong foundation for next-generation intelligent farming systems operating in adversarial and resource-constrained environments.

**Keywords:** Federated Learning, Smart Agriculture, Cyber–Physical Systems, Blockchain, High-Performance Computing, Sustainability

# PP-52: Deep Transfer Learning for Image-Based Structural Damage Recognition in Structural Health Monitoring

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**Introduction:** The critical need for rapid and objective damage assessment in modern infrastructure has driven a shift from manual inspections to data-driven Structural Health Monitoring (SHM) systems. Implementing effective automated assessment requires choosing modelling techniques that are both highly accurate and resource-efficient for specialized datasets. This research introduces a methodology that leverages Deep Learning to overcome the subjectivity of traditional methods. By utilizing Transfer Learning with the VGG16 architecture, the proposed system autonomously identifies complex damage patterns from visual data. Validation results demonstrate that this approach achieves a superior accuracy of 99.6% in detecting structural cracks. This study underscores the transformative role of Deep Transfer Learning in achieving autonomous, high-precision structural health assessments

**Methods and Material:** Managing the health of aging infrastructure is a significant challenge in civil engineering. While manual inspections have long been the standard, they struggle to scale with the increasing complexity of modern urban environments. To address these limitations, this paper proposes an innovative workflow that integrates a Convolutional Neural Network (CNN) into the SHM pipeline. At the core of this approach is VGG16, a deep architecture that uses 16 convolutional layers and 3x3 filters to hierarchically extract low- to high-level features representing damage. The methodology involves collecting crack and non-crack images from Mendeley and Kaggle, followed by pre-processing steps including resizing to 224x224 pixels and normalization. The model is fine-tuned using the Adam optimizer and Binary Cross-Entropy loss to optimize real-time classification.

**Result and Discussion:** Unlike basic CNN models or traditional machine learning techniques, the proposed VGG16-based system achieves a significant 99.6% accuracy rate in damage recognition. Comprehensive evaluations demonstrate the superiority of Transfer Learning in balancing computational efficiency with the need for high-fidelity feature extraction. The research also explores the deployment of this model into a functional web prototype, covering key aspects such as real-time detection and JSON-based response delivery. By enhancing objectivity in structural assessments, this research advances the creation of production-ready tools for field engineers. The following sections detail the data collection process, deep learning architecture, training parameters, and future integration with IoT and drones.

**Conclusion:** This research demonstrates the effectiveness of Deep Transfer Learning in optimizing image-based damage recognition for Structural Health Monitoring. The proposed VGG16-based system exhibits superior adaptability to specialized datasets, achieving near-perfect accuracy while maintaining the efficiency required for web deployment. Key findings highlight the impact of fine-tuning pre-trained networks and the use of dropout layers to prevent overfitting, validating the potential for autonomous structural assessment in real-world workflows.

**Keyword:** SHM, VGG, CNN, Deep Transfer Learning

# PP-53: A Multi-Layered Offline OCR Engine Powered With NLP Framework for Patient-Centric Lab Report Interpretation

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**Introduction:** India's healthcare market is currently in a hyper-growth phase, evolving from a multi-billion dollar sector to a trillion dollar industry by the end of this decade. In the same thread, India has an abysmally low percentage of people with access to decent healthcare. For about 300 million Indian citizens who live below the poverty line, medicine is prohibitively expensive while being ridiculously uninterpretable. Despite the billions spent, a vast majority of the population fails to fully understand the medical data they are paying for. The research behind the project 'ClarifAI' is built on the philosophy that a medical report shouldn't just be digitized as unintelligible numbers- it must be semantically reconstructed.

**Methods and Material:** The pipeline for the proposed solution starts with image enhancement using OpenCV: we convert scans to grayscale, upscale low-resolution images, apply Gaussian blur for noise reduction, deskew tilted pages, perform morphological operations to clean artifacts, and add borders for better edge detection. These optimized images feed into Tesseract OCR, selected for its reliability on printed text and no-internet requirement. Post-OCR, we segment tables and pinpoint test-value pairs via layout analysis (e.g., coordinates, page position). Moving beyond basic spaCy processing, we integrate a fine-tuned ClinicalBERT model to contextualize numbers- identifying them as HbA1c or TSH, for instance- and extract units. A custom Indian lab vocabulary, fuzzy matching, and regex backups handle OCR glitches, while physiological range checks flag anomalies for review rather than auto-fixes.

**Result and Discussion:** To address the 60% medical illiteracy rate in India's healthcare, we present an offline-first architecture that extracts, contextualizes, and visualizes diagnostic data with precision. This end-to-end approach extracts clean lab profiles from varied report formats without altering hospital workflows. Preprocessing counters Tesseract's weaknesses to skew and noise, boosting accuracy on real-world scans. BERT's contextual power cuts false positives in crowded layouts, distinguishing results from dates or references. Data flows to PostgreSQL and a React/TypeScript dashboard showing trends, color-coded risks, and everyday explanations tied to norms.

**Conclusion:** ClarifAI proves that a Tesseract-driven, transformer-enhanced setup can make opaque reports actionable and approachable. It's cost-effective, works offline, and scales across labs, with safeguards like clinician flags for safety. The research behind it aims to empower patients, reduce doctor workload, and provide a scalable, inexpensive, and accessible solution to lower healthcare costs through early risk detection and longitudinal trend analysis.

**Keyword**: ***Healthcare, OCR, Tesseract, NLP, Lab Report Summarizer***

# PP-54: Weakly Supervised Detection of Security Relevant Warnings in Medical Device Manuals Using Quantum Inspired Structural Features and Gradient Boosting

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**Introduction:** The rapid integration of Internet of Medical Things (IoMT) devices has revolutionized patient care but introduced significant cybersecurity vulnerabilities that threaten patient safety and data confidentiality. Traditional rule-based security systems are increasingly inadequate against these novel threats, often failing to process the highly technical language of device documentation or generating excessive false alarms. This study proposes a high-performance, quantum-enhanced hybrid machine learning framework designed to bridge the gap between robust threat detection and practical clinical deployment by automating the detection of safety-critical warnings in medical device manuals.

**Materials and Methods:** The research utilized the Global Medical Device Manuals Dataset 2025, comprising 2,694 regulatory records. To address ground-truth limitations and class imbalance, an enhanced ensemble labelling strategy was developed, merging keyword density, urgency patterns, and surrogate severity proxies. A hybrid feature space was constructed by integrating classical TF-IDF

n-grams with ten novel quantum-analog engineered attributes, including entropy, warning amplitude, risk superposition, and entanglement strength, resulting in a 1,510-dimensional representation. Five baseline classifiers were evaluated via stratified 5-fold cross-validation, with Gradient Boosting selected as the primary model. The architecture also integrated research-grade HMAC-SHA256 message authentication for cryptographic integrity.

**Results and Discussion:** Gradient Boosting achieved a test accuracy of 66.9%, a balanced accuracy of 66.0%, and an AUC-ROC of 0.705 on a held-out test set. The cryptographic subsystem demonstrated complete integrity reliability, and the threat-scoring module effectively stratified risks. However, a significant generalization gap was observed between training accuracy (99.55%) and testing accuracy, indicating overfitting attributed to the high-dimensional feature representation. While the system achieved a precision of 67.89%, minimizing false positives as required for clinical environments, recall was moderate at 53.7%, highlighting challenges in detecting subtle contraindications. Based on a composite performance metric, the system was classified as "Acceptable" for controlled clinical deployment.

**Conclusion / Recommendations:** The proposed framework establishes a reproducible baseline for automated safety surveillance, demonstrating that quantum-inspired feature engineering can effectively complement traditional natural language processing. While the system ensures operational continuity and data security, future iterations must address overfitting and recall limitations. Recommendations for future work include implementing advanced regularization, recursive feature elimination, and adaptive threat-detection thresholds to enhance generalization and situational awareness in evolving threat landscapes.

**Keywords**: Healthcare Cybersecurity, Internet of Medical Things (IoMT), Medical Device Security, Quantum-Inspired Machine Learning, Threat Detection Systems

# PP-55: Cloud-Integrated Digital Twin Framework for Intelligent Monitoring and Maintenance of Civil Infrastructure

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**Introduction:** Civil infrastructure is aging beyond design life, experiencing structural failures and escalating maintenance costs. *Problem:* Traditional Structural Health Monitoring (SHM) uses manual inspections and static thresholds, making it reactive, labor-intensive, and unable to capture dynamic behavior, causing undetected damage and costly failures. *Research Gap:* Digital twins and cloud-based SHM exist independently without unified integration of real-time synchronization, AI prediction, and optimization-driven maintenance. *Motivation:* Integrating digital twins with cloud and AI enables continuous monitoring, predictive detection, and cost-effective maintenance. This work proposes a cloud-integrated digital twin framework combining real-time sensor synchronization, machine learning prediction, and metaheuristic optimization.

**Materials and Methods:** The framework employs four-layer architecture: (1) Physical layer with strain and vibration sensors, (2) Cloud layer for scalable data ingestion and processing, (3) Digital twin layer maintaining virtual replica continuously updated with sensor data, (4) AI decision layer integrating predictive models and optimization. Sensor streams undergo noise filtering and normalization. Time-series machine learning models predict structural degradation. Metaheuristic optimization (Whale/Particle Swarm algorithms) balances safety and cost via: min(á·Risk + â·Cost). Experiments span 40 operational cycles on bridge infrastructure data comparing four baselines: threshold-based SHM, ML-only monitoring, digital twin without optimization, and optimization without digital twin. Metrics include synchronization accuracy, damage prediction accuracy, RMSE, alert precision, cumulative maintenance cost, and cloud latency.

**Results and Discussion:** Quantitative results demonstrate superior performance: (1) Synchronization accuracy remained >90% across all 40 cycles while baselines degraded steadily; (2) Damage prediction achieved consistently highest accuracy with lowest RMSE-threshold-based SHM ineffective for early detection; (3) Alert precision substantially improved-threshold-based generated high false positives, ML-only remained noise-sensitive, proposed framework achieved highest precision with reduced false alarms; (4) Cumulative maintenance cost lowest over time-static strategies accumulated costs rapidly, proposed framework aligned damage severity with intervention timing achieving sustained cost savings; (5) End-to-end latency within acceptable bounds despite synchronization overhead. Continuous digital twin synchronization with AI prediction and cost-aware optimization creates closed-loop intelligence, enabling proactive, economically informed maintenance.

**Conclusion:** This cloud-integrated digital twin framework achieves stable damage prediction (>90% synchronization accuracy), higher alert precision, and lower cumulative maintenance costs compared to conventional and partially integrated methods. Acceptable cloud latency confirms practical viability for smart infrastructure applications, demonstrating that tightly coupling digital twins with cloud-based AI and optimization enables reliable, cost-effective infrastructure monitoring.

**Keywords:** Digital Twin, Structural Health Monitoring, Cloud Computing, Predictive Maintenance, Smart Infrastructure

# PP-56: Human-Guided Reinforcement Learning for Cloud Orchestration

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**Introduction:** Modern cloud environments demand sophisticated resource allocation, workload scheduling, and dynamic scaling that simultaneously optimize performance, cost, and energy consumption. Traditional reinforcement learning (RL) enables automated orchestration through adaptive policy learning but struggles with incomplete reward specifications, sparse feedback, and limited training data, leading to suboptimal or unsafe behavior. Human-Guided Reinforcement Learning (HGRL) integrates human expertise through feedback, constraints, and interventions, enabling faster convergence, improved safety, and better alignment with organizational objectives through domain knowledge and strategic judgment.

**Materials and Methods:** This study reviews 42 publications from IEEE Xplore, ACM Digital Library, SpringerLink, ScienceDirect, and Google Scholar (2017–2025), focusing on RL applied to cloud orchestration with explicit human guidance mechanisms: reward shaping, demonstrations, preference modeling, or interventions. A comprehensive taxonomy classifies HGRL into four types: (A) Bootstrapping-upfront expert demonstrations; (B) Active Learning-continuous operational feedback; (C) Safety-Constrained-hard safety rules with soft interventions; (D) Hybrid Multi-Modal-combining multiple guidance mechanisms. The framework maps guidance methods to orchestration tasks including resource allocation, auto-scaling, load balancing, energy management, and workload scheduling, integrating with Proximal Policy Optimization (PPO) and Deep Q-Networks (DQN).

**Results and Discussion:** HGRL demonstrates substantial improvements across key metrics. In a Kubernetes-based microservices auto-scaling case study, HGRL achieved 98% SLA compliance versus 92% (RL-only) and 85% (manual). Makespan reduced 45.8% compared to manual scheduling and 27.8% versus RL-based orchestration. Cost per task decreased 50% versus manual ($0.60 vs $1.20) and 33.3% versus RL-only, with over-provisioning reduced from 28.5% to 8.3%. Resource utilization improved to 83%, representing 38.3% enhancement over manual and 10.7% over RL-based approaches. Training convergence time reduced approximately 50%, with human interaction declining after initial training phases. Reward shaping accelerates convergence, demonstrations reduce training samples by 30–70%, preference learning provides 2–3 times more consistent feedback, and safety interventions prevent catastrophic actions.

**Conclusion:** HGRL effectively manages complex cloud infrastructures by combining statistical learning with human insight, reducing training data requirements up to 70% while improving SLA compliance and decision transparency. Challenges persist in scalability, feedback consistency, and autonomy-oversight balance. Future research should prioritize AI-assisted feedback mechanisms, verified RL with formal safety guarantees, multi-objective preference learning, intuitive interfaces, sustainability-aware reward functions, and transfer learning. HGRL frameworks integrating adaptive learning, human judgment, and ethical oversight will enable intelligent, transparent, and responsible cloud management.

**Keywords:** Human-in-the-Loop, Reinforcement Learning, Cloud Orchestration, Resource Optimization, Adaptive Systems, Sustainability

# PP-57: Countermeasures against Hardware Trojans in Healthcare Devices based on Machine Learning Mathematical Models and IoT

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**Introduction**: The growing implementation of integrated circuits (ICs) into both conventional computing systems and Internet of Things (IoT) devices has created security problems because hardware Trojans introduce detrimental changes that compromise system security and system performance and system data protection. The traditional detection methods which include functional testing and side-channel analysis face challenges because they lack proper scalability and their detection performance and system analysis capabilities fall short.

**Methods**: The research paper demonstrates a machine learning system which detects hardware Trojans by analyzing simulation data and actual hardware measurements. The digital microfluidic biochip functions as a healthcare device which monitors blood glucose levels, blood pressure measurements and various other medical conditions. We created a complete dataset based on Trust-HUB benchmarks which includes FPGA designs and power consumption data and switching event data. The dataset quality improves through data preprocessing methods which include noise removal techniques and normalization methods and Principal Component Analysis (PCA) dimensionality reduction. The research investigated multiple machine learning algorithms which include Logistic Regression (LR) Random Forest (RF) Gradient Boosting (GB) Support Vector Machine (SVM) K-Nearest Neighbor (KNN) and Multilayer Perceptron (MLP).

**Results**: The experimental results showed that the LR and GB algorithms achieved the best trade-off among the three factors including accuracy, computational efficiency, and detection delay; thus, they are suitable for real-time applications in embedded systems and IoT devices, and MLP obtained the highest detection rate.

**Conclusion**: The findings presented in this paper indicate that machine learning can indeed serve as the most effective benchmark for hardware Trojan detection as opposed to conventional methodologies, and presents a reliable scalable solution for security practitioners to implement towards real-world security. The advancement of machine learning technology allows system enhancement in a continuous manner so that it improves its threat stopping ability and maintains the FP rate at an acceptable level.

**Keywords:** Hardware Trojan, Machine Learning, Integrated Circuits, FPGA

# PP-58: MedFusion: A Unified Multimodal Framework for Visual Question Answering and Explainable Medical Recommendation

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**Introduction:** Artificial intelligence (AI) has played a transformative role in modern healthcare by enabling automated analysis of medical images, clinical reports, and patient data. Recent advances in deep learning have significantly improved medical image interpretation, radiology reporting, and computer-aided diagnosis. However, most existing AI systems are designed to solve isolated tasks, such as visual question answering (VQA) or medical recommendation, independently. In real clinical practice, physicians rarely operate in this fragmented way. Instead, they analyze medical images, ask clinically relevant questions, and expect not only accurate answers but also actionable, evidence-based recommendations that can guide diagnosis and treatment. To address this critical gap, we propose MedFusion, a unified multimodal framework that integrates medical VQA, personalized recommendation, and explainable AI into a single end-to-end system. Given a medical image (such as a chest X-ray) and a clinician's natural-language question, MedFusion simultaneously generates a clinically meaningful answer and a context-aware recommendation. In addition, the system provides human-interpretable explanations to enhance transparency and trust. By combining these three capabilities, MedFusion moves beyond conventional diagnostic tools and functions as an intelligent clinical assistant capable of supporting real-world decision making.

**Methods and Material:** MedFusion employs a multimodal deep learning architecture that jointly models visual and textual information. Medical images are processed using a hybrid vision encoder based on ResNet-50 and Vision Transformer (ViT) to capture both local anatomical features and global contextual patterns. Clinical questions are encoded using Sentence-BERT (SBERT) to obtain rich, context-aware semantic representations. A co-attention-based fusion module aligns visual regions with question tokens, allowing the model to focus on clinically relevant image areas corresponding to the query. To further enhance reasoning, a retrieval-augmented module dynamically retrieves similar medical cases and external clinical knowledge, improving factual grounding and reducing hallucination. For recommendation, the model shares the fused multimodal representation and uses a GAN-guided augmentation strategy to generate idealized reference images, enabling more accurate and personalized suggestions even in data-sparse scenarios.

**Result and Discussion**: MedFusion was evaluated on VQA-RAD, EHRXQA, and Med-RecX datasets. The proposed joint model achieved 76.8% VQA accuracy, outperforming VQA-only baselines by 7.4%. For recommendation tasks, MedFusion produced lower RMSE and MAE values, indicating more accurate prediction of clinically relevant recommendations. The explainability module, which combines attention heatmaps with natural-language rationales, received a human evaluation score of 4.5 out of 5, significantly higher than visual-only or text-only explanation methods. These results demonstrate that shared multimodal reasoning and retrieval-augmented learning substantially improve both performance and trustworthiness.

**Conclusion:** MedFusion provides a powerful and transparent multimodal framework for healthcare decision support by integrating VQA, recommendation, and explainability. Its ability to generate accurate, personalized, and interpretable outputs makes it highly suitable for real-world clinical deployment in radiology and tele-health environments.

**Keyword:** ***Multimodal Learning, Medical VQA, Explainable AI, Clinical Recommendation, Co-Attention, GAN-based Augmentation***

# PP-59: Intelligent Respiratory Disease Classification using ML and DL: Asthma vs COPD for Early Detection.

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**Introduction:** Asthma and Chronic Obstructive Pulmonary Disease (COPD) are common lung diseases that cause breathing problems. These lung diseases have similar symptoms such as coughing, wheezing, chest tightness, and shortness of breath. These similar symptoms make it difficult for doctors to correctly diagnose these lung diseases at the early stage. It is important to differentiate these lung diseases early and accurately because the management of these lung diseases is different from one another. The main objective of this research is to use the ML and DL techniques to differentiate between asthma and COPD as the first step in the pre-detection of asthma.

**Materials and Methods:** This study utilizes publicly available data sets that include features like FEV1, FVC and FEV1/FVC ratio. This study uses the Radom Forest and XGBoost algorithms as the main machine learning models due to their high performance in classifying healthcare data. In addition, the study uses the Support Vector Machine (SVM) and Logistic Regression models as baseline models for comparison. In deep learning models, the study uses a Multilayer Perceptron Artificial Neural Network for handling nonlinear relationships. It also considers using Long Short-Term Memory (LSTM) networks for future use in respiratory time-series monitoring.

**Results and Discussion:** It is observed from the results that the ensemble models of ML, i.e , Random Forest and XGBoost, show robust performance for classification tasks, whereas the DL models can be used for identifying complex relationship in the data, particularly when the patient data is collected over period of time. The lung function test values and the features related to the symptoms also have a major impact on improving the accuracy on the predictions. From the discussion, it is inferred that the ML models can be interpreted more easily and can help doctors understand the decision-making process, whereas the DL models can identify hidden patterns that may not be obvious using conventional techniques. However, the challenges persist in terms of availability of data, class imbalance, and the need for validating the models in real-time using IoT-based sensor technology.

**Conclusion:** Thus, in conclusion, the results of this research indicate that the integration of Machine Learning and Deep Learning methods can assist in the early differentiation of asthma and COPD, which is an essential step towards the development of asthma pre-detection systems. Intelligent systems can assist healthcare professionals in making quick decisions, which can lead to better results in the future. Future directions of this research include the integration of real-time sensors, improving the interpretability of the models, and developing secure healthcare systems.

**Keyword:** Asthma pre-Detection, COPD Classification, Long Short-Term Memory, XGBoost, Healthcare Analytics.

# PP-60: Mitigating Dataset Bias in EMG Controlled Prosthetic Systems Through Fairness-Aware Machine Learning

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**Introduction:** The trend towards the integration of artificial intelligence in smart prosthetic devices has made intuitive man-machine interfaces possible with the help of electromyography (EMG). However, the bias that exists in machine learning models, especially with the use of limited, imbalanced, and non-representative data, may affect the overall functioning of prosthetic devices for some users, and therefore, it is crucial to address the bias in prosthetic AI devices.

**Methods and Materials:** Machine learning classifiers for prosthetic movement prediction were trained using EMG hand-gesture datasets. Subject imbalance, class distribution skew, and controlled signal variability were used to introduce bias conditions. The baseline models were assessed in their original form, without applying any bias mitigation techniques. Fairness-focused approaches such as data resampling, weighted loss functions, and signal normalisation were introduced only after this initial evaluation to measure their impact more clearly. Model performance was assessed using accuracy, group-wise error rates, and fairness metrics.

**Results and Discussion:** The results of EMG-based prosthetic gesture recognition demonstrated that there was a degree of bias, as quantified performance differences were seen across the baseline models for different simulated user groups. The implementation of mitigation techniques improved accuracy for minority groups, reduced performance gaps, and increased robustness, albeit with a small loss in overall accuracy.

**Conclusion:** The fairness and consistency of the machine learning models applied to the EMG-controlled smart prosthetics can significantly be influenced by the bias present in the dataset. By improving the fairness and consistency of the machine learning models through the incorporation of fairness-aware training mechanisms, more fair and consistent intelligent prosthetics can be developed. Future clinical deployment will require a sustained focus on diverse data collection and bias-aware evaluation.

**Keyword:** ***Electromyography, Fairness-aware training, Bias Mitigation Techniques, Data Resampling, Weighted loss functions***

# PP-61: A Cyber-Physical System Framework for Classifying and Detecting Attacks in Critical Infrastructures

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**Introduction**: Cyber Physical Systems (CPS) is the combination of computer intelligence with the physical process for the purpose of facilitating automation in the system with real-time monitoring and control of critical infrastructure. Even though the mixture of the cyber world with the physical world enhances the usability of the system in terms of increasing the degree of automation in the system, it also opens the network for a list of security risks. Hence, the present study aims at developing a machine learning-based framework for detecting cyber-attacks with the help of the machine learning technique.

**Methods**: A hybrid CPS testbed has been implemented to conduct realistic scenarios. The scenarios included normal behaviour and attacking scenarios concerning DoS/DDoS attacks, which were generated in a controlled environment for isolated networks. Other parameters were collected by capturing protocol packets in PCAP format to create structured dataset and by synchronizing critical parameters to ensure cyber-physical consistency in the features. The features extracted included protocol models, statistical characteristics and timing attributes. In this study, the application of the Mutual Information method was used to select significant features for classification. Several models were used; however, the most prominent ones were supervised models. For tuning the parameters, a hybrid model of combining Grid Search Optimization with Particle Swarm Optimization was implemented to optimize accuracy on a validating model.

**Results**: From the experimental results, hyperparameter tuning is shown to enhance the performance of the model. Accuracy is enhanced for the classifier implemented using the decision tree model, reaching 98.95%, compared with the random forest and gradient boost models, which achieved 97.68% and 97.53%, respectively. Moreover, the performance of the models was improved for the KNN and AdaBoost models, while there was a marked decrease in the linear model classifier, showing their non-linear nature of CPS attack types. Validation was performed, showing the model has good generalization performance with low misclassification.

**Conclusion**: The suggested CPS security framework provides effective detection as well as classification of cyber-physical attacks by utilizing supervised learning techniques in fusion with hybrid hyperparameter optimization techniques. Feature selection by using Mutual Information, as well as parameter tuning via PSO as well as improved Grid Search, enhanced the accuracy of the suggested detection system. The results proved the effectiveness of optimized tree as well as ensemble-based models, which provide robust as well as reliable security against various types of evolving cyber-physical attacks on CPS-based critical infrastructure.

**Keywords:** Cyber-Physical Systems, Intrusion Detection, Attack Classification, Particle Swarm Optimization, Critical Infrastructure Security.

# PP-62: Deep Learning Based Camouflaged Object Detection from Multi Spectral Images

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**Introduction:** Camouflaged Object Detection (COD) is a challenging area of computer vision that focuses on detecting objects hidden within complex backgrounds. Unlike general object detection, camouflaged objects closely resemble their surroundings in color, texture, and structure, making them difficult to identify. Although deep learning has improved COD performance, RGB-based methods still face limitations under extreme camouflage conditions. This research proposes an improved deep learning framework for multispectral camouflaged object detection, emphasizing hierarchical feature learning, boundary enhancement, context modelling, and cross-modal fusion. The goal is accurate pixel-level segmentation with refined boundaries, better robustness, and improved generalization, supporting applications in Défense, surveillance, medical imaging, wildlife monitoring, and remote sensing.

**Methods and Material:** This research presents the proposed camouflaged object detection framework, with emphasis on the design of an improved feature extraction technique for accurate segmentation in low-contrast and complex environments. The methodology is developed using a deep learning–based encoder–decoder architecture, incorporating adaptive multispectral feature fusion, boundary-aware feature refinement, and multi-level hierarchical feature learning. Each module is described its functional role, architectural design, while the materials include benchmark COD datasets and standard evaluation metrics. This combination enables improved segmentation accuracy and boundary preservation in camouflaged object detection tasks.

**Result and Discussion**: The proposed cross-scale feature learning framework achieves superior performance compared to existing camouflaged object detection (COD) methods across multiple benchmark datasets. Proposed model shows significant improvements in segmentation accuracy, structure measure, and boundary preservation metrics. The model effectively enhances foreground–background discrimination by integrating multi-scale contextual information, leading to clearer object localization and sharper boundaries. It consistently outperforms traditional handcrafted approaches and recent deep learning–based COD models. This approach provides a more reliable framework for real-world applications where low contrast and background similarity pose major challenges.

**Conclusion:** This research shows that deep learning–based camouflaged object detection methods have greatly improved the ability to detect and segment objects in low-contrast and complex backgrounds. Techniques such as multi-level feature fusion, context-aware modeling, boundary-guided learning, and adaptive feature partitioning enhance both foreground–background separation and boundary accuracy. These models effectively combine local details with global context, outperforming traditional handcrafted and RGB-only methods. Overall, strong feature representation and adaptive integration of multiple cues are key to accurate camouflaged object detection.

**Keyword:** ***Camouflaged Object Detection, Multispectral Imaging, Deep Learning, Feature Extraction, Boundary-Aware Segmentation***

# OP-63: Optimal Operation of Transmission System Integrated with FACTS Devices and Renewable Energy Sources

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**Introduction:** The rapid integration of renewable energy sources and advanced power electronic controllers into transmission networks has significantly increased the complexity of modern power system operation. Wind energy integration through multi-terminal transmission lines and the deployment of Flexible AC Transmission System (FACTS) devices such as the Unified Power Flow Controller (UPFC) introduce dynamic challenges in power flow control, stability, and protection. This work focuses on the optimal operation of a high-voltage transmission system integrated with a UPFC and a wind farm connected through a tapped transmission line.

**Methods and Material:** A 500 kV transmission network with three substations interconnected through a 400 km tapped line is modeled in MATLAB/Simulink. A 100 MVA UPFC is installed at the midpoint of the line, and a 60 MW wind farm based on Doubly Fed Induction Generators (DFIG) is connected at the tapped point. Three-phase current signals are sampled at 20 kHz and processed using Discrete Wavelet Transform (DWT) and Discrete Fourier Transform (DFT) to extract fundamental components. An energy-based analytical framework is developed using operating and restraining spectral energies derived from measured currents to assess system behavior under various operating and fault conditions.

**Result and Discussion:** Extensive simulations are conducted for different fault types, fault resistances, fault locations, and wind speed variations. Results indicate that the proposed energy-based approach reliably distinguishes system conditions despite the presence of UPFC control actions and fluctuating wind generation. The integration of FACTS devices enhances controllability, improves voltage stability, and supports optimal power flow while maintaining reliable system performance under dynamic conditions.

**Conclusion:** The study demonstrates that advanced signal processing techniques combined with FACTS devices and renewable energy integration enable secure and optimal operation of complex transmission networks. Future work may involve real-time implementation and extension to multi-renewable integrated systems.

**Keyword:** ***FACTS, UPFC, Wind Farm, DWT, DFT, Transmission Line, Renewable Integration, Energy-based Analysis***

# OP-64: Performance Enhancement of Radial Distribution Networks through Optimal DG Placement under Static and Seasonal Loading

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**Introduction:**Radial distribution systems represent the final stage of electric power delivery and are inherently prone to higher power losses, poor voltage regulation, and reduced reliability due to their radial structure and high resistance-to-reactance (R/X) ratio. The integration of Distributed Generators (DGs), such as photovoltaic (PV) systems and wind turbines (WT), has emerged as an effective solution to enhance distribution network performance. However, improper siting and sizing of DG units may cause adverse impacts, including reverse power flow and voltage violations. Therefore, optimal placement and sizing of DGs are essential to maximize technical benefits.This study proposes an optimization-based framework for optimal DG allocation in a radial distribution system considering both fixed load conditions and seasonal load variations. Unlike conventional approaches that assume constant loading, the inclusion of seasonal variability provides a realistic representation of practical operating conditions, ensuring robust and sustainable planning decisions.

**Materials and Methods:** The study is based on a radial test system such as IEEE 33-bus, incorporating detailed electrical parameters including bus loads, line impedances, and base voltage ratings. The system serves as a platform to analyze DG integration impacts.Both fixed and seasonal load scenarios are examined to reflect steady and dynamic operating conditions. Seasonal modeling improves the reliability of planning outcomes.BFS load flow is employed due to its compatibility with radial topology and high R/X ratio. The iterative sweeps ensure accurate voltage and current calculations.The optimization aims at loss reduction, voltage improvement, and reliability enhancement under operational constraints. A metaheuristic algorithm is used to determine optimal DG placement.

**Results and Discussions:**Simulation results indicate substantial performance enhancement after optimal DG placement. Under fixed load conditions, total real power losses are significantly reduced compared to the base case without DG integration. Voltage magnitudes across buses are improved, particularly at the weakest buses located far from the substation.When seasonal load variations are considered, the proposed approach maintains improved voltage stability and consistent loss reduction across different loading conditions. This demonstrates the robustness and adaptability of the optimization framework. Furthermore, distributed generation support reduces feeder stress and contributes to improved reliability performance.Comparative analysis confirms that DG planning based on seasonal load modeling provides more realistic and technically reliable solutions than optimization based solely on fixed load conditions.

**Conclusion:**This study presents a comprehensive optimization framework for the optimal placement and sizing of Distributed Generators in radial distribution systems under both fixed and seasonal load conditions. The results demonstrate significant reduction in power losses, enhancement of voltage profile, and improvement in reliability performance. Incorporating seasonal load variability improves the practical applicability and robustness of DG planning strategies. The proposed methodology can serve as an effective tool for distribution system planners aiming for efficient and sustainable DG integration.

**Keywords:**Distributed Generation (DG), Radial Distribution System, Seasonal Load Variation, Voltage Profile Improvement, Reliability Enhancement, Metaheuristic Optimization.

# OP-65: Design and Optimization of AVR and VI -Integrated Microgrid with PID and TID Controllers for Frequency Regulation and Voltage Stability Using Particle Swarm Optimization

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**Introduction:** Microgrids, small-scale power systems, are a promising solution for maximizing renewable energy use and improving grid dependability. However, controlling energy flow, maintain the frequency and voltage stability particularly with intermittent renewable energy sources and integration of Electric Vehicle and Electric Aircraft carrier, is challenging. To address this, the integration of automatic voltage regulator and virtual inertia using inverter controls and fast storage devices, along with Load Frequency Control (LFC) to restore nominal frequency and support voltage regulation.

**Materials and Methods**: The frequency regulation and voltage profile improvement of the grid connected microgrid with renewable energy sources, EV and EAC is achieved with automatic voltage regulator (AVR) and Virtual inertia (VI) support. Particle swam optimization algorithm is used to tune the PID and TID controller to regulate the frequency deviation and improve the voltage profile. The introduction of virtual inertia significantly enhanced the microgrid's transient stability by emulating synchronous behavior and delivering rapid active-power compensation during disturbances.

**Results and Discussion:**

The TID controller outperforms the PID control in terms of settling time, overshoot, and transient behavior, according to LFC results. For both constant and variable loads, the TID controller has a 50% reduced settling time than the PID controller. Likewise, the comparison of AVR-based LFC for constant and variable load reveals less overshoot and less settling. With VI-supported microgrids, settling time is reduced by 40% and overshoot is reduced by 65%. Comparison of TID controllers for AVR and VI-based microgrids reveals that VI support reduces settling time by 11% and overshoot by 54%. The TID controller maintains its enhanced voltage stability in variable-load circumstances, showing less long-term fluctuation and a smaller oscillation amplitude.

**Conclusion/Recommendation:**

Controllers, particularly PID and TID, were enhanced through the ITAE criterion and Particle Swarm Optimization (PSO), leading to improved settling time, reduced overshoot, and better damping. Simulations showed that coordinated voltage and frequency regulation facilitates smoother dynamics and reliable operation for airport loads. The study underlines the effectiveness of virtual inertia combined with finely tuned controllers for low-inertia microgrid resilience, recommending further research into advanced wind turbine generation and battery energy storage systems, as well as a cost-benefit analysis for controller implementation.

**Key words**: ***Microgrid, Electric Aircraft Carrier (EAC), Frequency regulation, Particle swarm optimization, Renewable Energy***

# OP-66: Reduced Component Transformer Based Multilevel Inverter

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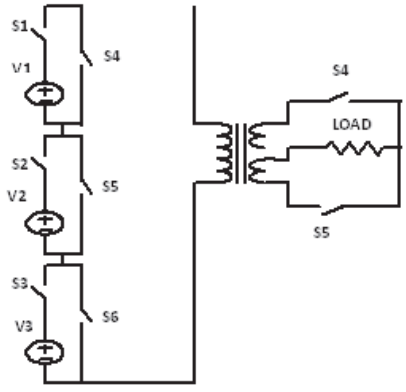
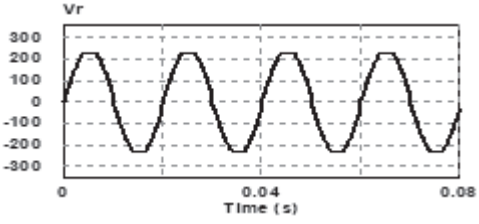
**Introduction:** This paper presents the design of an asymmetric multilevel inverter generating maximum voltage levels with an optimal number of circuit components. The main objective is to develop a multilevel inverter with low total harmonic distortion (THD), reduced voltage stress, and high efficiency. The proposed topology is developed to produce 15 voltage levels. A transformer at the output boosts voltage with a half-bridge circuit at the secondary terminal for polarity reversal. Switching pulses are generated using the Nearest Level Control (NLC) method. The circuit improves component count, voltage stress, and THD. Simulation and result verification are performed to validate the proposed circuit.




**Proposed Topology**: The proposed circuit includes three DC voltage sources arranged in the ratio 1:2:4, together with three switches and three bypass diodes. A transformer is employed to increase the voltage level, and two extra switches are placed at the secondary side to achieve polarity reversal. The figure illustrates the overall circuit structure. Whenever a switch is turned on, its corresponding bypass diode becomes reverse biased and remains off, whereas turning the switch off allows the diode to conduct. In this manner, each section can supply either zero or its respective source voltage. With V1:V2:V3 maintained at 1:2:4, their binary combination generates seven distinct voltage levels. Switches S4 and S5 provide polarity reversal by operating alternately in each half cycle.




**Results and Discussion**: Simulated output results are presented to confirm the performance and claims of the proposed MLI. The analysis is carried out using the PSIM platform to verify the effectiveness of the designed circuit. For the study, the input DC voltages are selected as 6 V, 12 V, and 24 V, with a transformer turns ratio of 1:6:6. Fundamental frequency is maintained at 50 Hz. The figure depicts the secondary voltage waveform under a purely resistive load of 100 ohms. The waveform appears smoother due to the natural filtering provided by the transformer leakage inductance. The THD for this resistive load condition is approximately 5.6%.

**Conclusion/Recommendation:** The paper describes the design of a multilevel inverter that is simple and robust while utilizing an optimal number of components. A reduced switch count also lowers the requirement for gate driver circuits, making the MLI more practical and easier to implement. The transformer ensures electrical isolation between input and output, improving fault tolerance and providing safety for the low-voltage primary side. It further assists in significantly decreasing the voltage stress across the level-generating switches. The proposed system can be efficiently integrated with renewable energy sources at the primary side and applied in areas such as grid integration, electric vehicles, or standalone inverter systems.

**Key words**: total harmonic distortion (THD), voltage boost, polarity reversal.

# OP-67: A Hybrid CNN-BiGRU Attention Model for Robust Fault Detection in AC Microgrids

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**Introduction:** Fault detection in AC microgrids (MGs) is a critical challenge due to low fault currents, bidirectional power flow, and increasing integration of distributed energy resources. Conventional protection techniques based on magnitude or sequence components often fail under such dynamic conditions. To address these limitations, this study proposes a hybrid deep learning framework combining Convolutional Neural Network (CNN), Bidirectional Gated Recurrent Unit (Bi-GRU), and an Attention mechanism for accurate and reliable fault detection in a seven-bus AC microgrid system.

**Methods and Materials:** A seven-bus AC microgrid was modeled and simulated in RSCAD using a Real-Time Digital Simulator (RTDS) environment to generate realistic operational data. Various fault types, including LG, LL, LLG, LLL, and LLLG, were introduced. Three-phase current signals (90×3 sequence) were used as input features. Data preprocessing included signal labeling (0.2–0.4 s fault window), absolute value conversion, standardization using a Standard Scaler, and sliding-window segmentation. The proposed architecture consists of Conv1D (128 filters) for local feature extraction, MaxPooling for dimensionality reduction, Bi-GRU (64 units) for temporal dependency learning, and an Attention layer for emphasizing fault-relevant time steps. A Dense layer with Softmax activation performs binary classification (fault/no-fault). The model was trained using cross-entropy loss, adaptive learning rate scheduling, early stopping, and data augmentation to improve generalization.

**Result and Discussion:** The proposed hybrid CNN-BiGRU Attention model achieved up to 99% accuracy, outperforming traditional classifiers such as Decision Tree (DT), Support Vector Machine (SVM), and Naïve Bayes (NB). For LLG faults, the model achieved an Average Precision (AP) of 0.99 and an AUC of 0.99, demonstrating excellent discriminative capability. Training and validation curves showed smooth convergence without significant overfitting. The attention mechanism improved interpretability by identifying critical waveform segments responsible for classification decisions. Compared to conventional ML methods, the proposed framework exhibited superior robustness, scalability, and real-time applicability.

**Conclusion:** The study demonstrates that a hybrid deep learning approach integrating CNNs, Bi-GRUs, and Attention mechanisms significantly enhances fault-detection performance in AC microgrids. The method is communication-independent, cost-effective, and suitable for real-time deployment. Future work includes multi-class fault classification, real-time field validation, cybersecurity integration, and edge-based intelligent protection systems.

**Keywords:** Microgrid; Fault Detection; CNN; GRU; Attention Mechanism; Deep Learning; Time-Series Analysis; Adaptive Protection.

# OP-68: Performance Analysis of a High Gain Bidirectional DC-DC Converter Fed Drive for an Electric Vehicle

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**Introduction:** The growing adoption of electric vehicles (EVs) demands efficient power electronic interfaces capable of managing bidirectional energy flow between the battery and the drive system. High voltage gain DC–DC converters are essential for stepping up low battery voltages to the DC-link level while also enabling regenerative braking. Conventional isolated bidirectional converters suffer from increased losses, bulky magnetic components, and higher complexity, whereas many non-isolated high-gain topologies rely on voltage multiplier cells or switched-capacitor structures that introduce excessive component count, voltage stress, and ripple issues. This work presents a novel non-isolated High Gain Bidirectional DC–DC Converter (HGBDC) designed to achieve large voltage conversion ratios with minimal components and improved efficiency, making it suitable for EV drivetrain applications.

**Materials and Methods:** This HGBDC employs four active power switches, two identical inductors, a diode, and a high-voltage-side capacitor. High voltage gain is achieved using a dual duty-cycle control strategy without requiring voltage multiplier cells or coupled inductors. The converter operates in continuous conduction mode (CCM) and supports both boost (motoring) and buck (regenerative braking) modes. The system is modeled using MATLAB/ Simulink. A 5 HP separately excited DC motor and a lithium-ion battery are integrated to evaluate converter performance under practical driving conditions. A PID-based closed-loop controller regulates motor speed by adjusting the converter duty cycles.

**Results and Discussion:** The proposed converter demonstrates significant voltage gain capability, achieving gains exceeding those of comparable non-isolated converters within practical duty-cycle ranges. At higher duty ratios, a voltage gain of up to 32 is obtained. Efficiency analysis incorporating parasitic elements indicates theoretical efficiencies above 94% in boost mode and 95% in buck mode, closely matching simulation results. Dynamic performance evaluation shows stable operation during transitions between forward motoring and regenerative braking, with clear reversal of current and torque. Regenerative braking results confirm energy recovery and battery charging, with measurable improvement in battery state of charge. Step changes in motor speed reveal fast transient response and minimal oscillations, validating controller effectiveness. The reduced component count and absence of bulky magnetic elements enhance power density and practicality.

**Conclusion:** The HGBDC proposed for EV drive application offers an efficient, high-gain, and low-complexity solution for EV applications. The converter effectively manages bidirectional power flow, supports regenerative braking, and delivers high voltage gain with fewer components. Simulation results confirm its feasibility and dynamic robustness. Future enhancements may include SiC-based devices and soft-switching techniques to further improve efficiency at higher switching frequencies.

***Keywords:*** Bidirectional dc–dc converter, high voltage gain, electric vehicle, regenerative braking

# OP-69: Multi-Objective Meta-Heuristic Optimization of R–L–C Fault Current Limiter for Enhanced Protection in DC Microgrids

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**Introduction:**

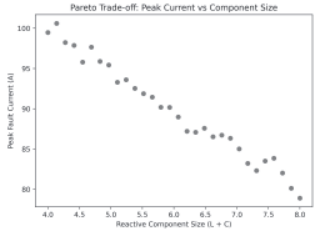
Low-voltage DC microgrids (LVDC-MGs) enable high renewable penetration and decentralized energy management; however, their converter-dominated architecture and low line impedance lead to rapidly rising fault currents. Conventional deterministic tuning of Fault Current Limiters (FCLs) does not adequately address nonlinear and conflicting design requirements such as peak fault limitation, component sizing, and voltage ripple control. This work presents a multi-objective meta-heuristic framework for optimizing R–L–C based FCL parameters in a looped DC microgrid.

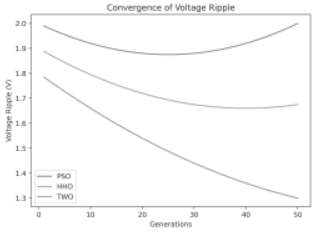
**Materials and Methods:**

A PSCAD-based looped DC microgrid model incorporating PV sources, battery energy storage systems, DC–DC converters, and feeder impedances is developed. The FCL is modelled as a series R–L–C element. A tri-objective optimization problem is formulated to minimize peak fault current, reactive component size (L+C), and voltage ripple, subject to practical constraints. Particle Swarm Optimization (PSO), Harris Hawks Optimization (HHO), and Tug-of-War Optimization (TWO) are implemented to extract Pareto-optimal solutions.

**Results and Discussion:**

Across 50 generations of optimization, all algorithms demonstrate progressive reduction in peak fault current. PSO exhibits rapid early convergence but stagnates later. HHO provides improved global exploration. TWO achieves the most consistent convergence, delivering the lowest peak fault current and voltage ripple.



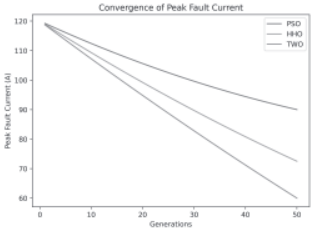




Figure 1. Convergence of Peak Fault Current Figure 2. Convergence of Voltage Ripple Figure 3. Pareto Trade-off: Peak Current vs Component Size

**Conclusion:**

The study demonstrates that multi-objective meta-heuristic optimization significantly enhances FCL design for LVDC microgrids. Tug-of-War Optimization provides superior convergence stability and balanced trade-offs between transient limitation and steady-state performance.

**Keywords:**

Harris Hawks Optimization ,Meta-Heuristic Optimization, Multi-Objective Optimization

# OP-70: Improving Utility Systems' Power Quality with Adaptive Algorithm-Based DSTATCOM

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**Introduction:** The architecture and functionality of a distributed static compensator (DSTATCOM) based on a Cross Least Mean Square (X-LMS) neural network (NN) for shunt compensation are presented in this work. Harmonics correction, power factor (p.f.) upgrading, load balancing, and voltage control at the supply bus are first achieved by taking into account the adaptive least mean square (ALMS) technique. Second, the active and reactive components of load current are mathematically examined by updating their respective weights, based on the X-LMS concept. The primary goal is to use the proposed adaptive concept to extract the tuned weighted values of the fundamental active and reactive power components of distorted load currents. Better convergence speed, significant computational savings, and avoidance of the extra filtering required by the ALMS structure are all features of the X-LMS. Lastly, MATLAB/ Simulink is used to construct the X-LMS model for simulation research. In order to demonstrate improved power quality (PQ) of the distribution system, the X-LMS parameter design can be utilized to enhance harmonic reduction with additional compensating performances.

**System Description**: The proposed system consists of a distribution system using DSTATCOM. The compensator or interface impedance (Zc) is used in this arrangement to link the DSTATCOM at point of common coupling of distribution system. Reactive power, distribution system recruitment, and the extent of non-linear loads all affect the compensator's power rating.

$$v_{dc} = \frac{2\sqrt{2} \times V_L}{\sqrt{3} \times m_i} \quad (1)$$

$$C_{dc} = \frac{P_{rated}}{v_{dc}(2 \times \omega \times S_f(v_{dc(ripple)})} \quad (2)$$

**Results and Discussion** This section uses simulation with MATLAB/SIMULINK software to evaluate the performance of the X-LMS based DSTATCOM over ALMS. Two distinct loading states steady-state and transient state are Anlysed. The two methods' relative performance is shown in terms of PQ improvement for various scenarios. The simulation parameters are kept constant for all types of investigations.

**Conclusion/Recommendation:** We presented an adaptive X-LMS control approach for DSTATCOM operation in this study. According to the benchmark value of the international standard, it improved the stability and PQ improvement of distribution system with more efficiency during steady-state and transient-state conditions. The X-LMS learning principle is used in the mathematical study to obtain the filter weight from the load current's clustered weight. Through simulation modeling, the control techniques have been analytically validated for various loading scenarios.

**Key words**: ALMS; X-LMS; DSTATCOM; Distribution System

# OP-71: Enhancement of Transient Stability of Hybrid Electric Power System Using AI technique

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**Introduction**: In order to make multi-area power systems more efficient and stable, this study aims to create a new intelligent controller design based on adaptive property. The integrated power grid becomes more unstable as renewable energy sources become more prevalent, and system inertia decreases. Resultant, the penetration of renewable and load variance causes frequency changes to be more pronounced. Keeping frequency stable is essential for the electrical energy transmission system to work reliably and efficiently. Power system safety, reliability, and efficiency are all put at risk when frequencies deviate too far from their normal values. The transmission stability of power system plays a critical role to maintain grid reliability during disturbances such as faults, switching operations or system load variations. Hybrid Electric power System (HEPS) which integrate renewable energy sources (such as wind, solar, and hydro) with traditional generation and energy storage systems, introduce unique challenges and opportunities for transient stability of HEPS under various dynamic condition. The main objective of this study is to investigate the transient stability characteristics of HEPS and develop techniques to mitigate instability during system disturbances. First a comprehensive modelling framework for Hybrid systems including renewable sources, energy storage, and conventional generators will be developed. The dynamic behavior of the system under fault condition will be analyzed. Advanced control strategies such as power system stabilizers (PSS) and energy storage system (ESS) optimization will be explored.

**Methods**: This study introduces an adaptive Tilt Fractional Order Proportional-Integral-Derivative (TFOPID) controller, optimized using the Tunicate Search Algorithm (TSA), to enhance frequency stability in interconnected power systems. The controller's gains ($K_P$, $K_I$, $K_D$ and $K_T$) are dynamically adjusted by an ancillary TPID controller in response to frequency changes. Implemented in northern and southern regions comprising photovoltaic, wind, redox flow battery, hydro, and thermal power plants, The TFOPID and TPID parameters are optimized with the support of tunicate search algorithm. Once the best settings for the controller have been determined, the TFOPID controller continuously updated online through the TPID controller This approach aims to create more resilient and efficient power grids, essential for integrating renewable energy sources and meeting the growing demand for sustainable power solutions.

**Results and Discussion**: The gains of the TFOPID controller are continuously updated by utilizing the ancillary TPID controller to stabilize the area frequencies within prescribed limit. The suggested control system is implemented in the northern and southern regions, which consist of photovoltaic (PV), wind, redox flow battery (RFB), hydro, and thermal power plants.

**Conclusion**: This research will contribute significantly to the growing body of knowledge on hybrid power systems and provide essential tools for system operators and engineers to enhance the resilience of future power grids. It will also support the transition to more sustainable, low-carbon energy systems by ensuring the stability of grids with high penetration of renewables.

**Keywords**: Hybrid Electric Power System, Transient Stability, Energy Storage Systems, Renewable Energy, Power System Stabilizer, AI-based Control, Optimization, Faults, Grid Stability.

# OP-72: Load Frequency Control of Microgrid integrating Electric Vehicles with state of Charge control using Marine Predator Algorithm

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**Introduction:** A Standalone microgrids (SMGs) suffer from frequency deviations due to the intermittency of renewable energy sources and low system inertia. While energy storage systems provide partial mitigation, their high cost limits large-scale deployment. This study proposes the integration of electric vehicles (EVs) using state-of-charge–based synchronous control and a Marine Predator Algorithm–tuned Tilt Integral Derivative (TID) controller for load frequency control. Simulation results demonstrate significant reductions in overshoot, undershoot, and settling time, thereby enhancing SMG stability and reliability.

**Modelling of Microgrid:** The SMG model comprises various DES units (PV, WTG, FC, DEG, MT) and storage devices (BESS, FESS). EVs are integrated using SoC-synchronous control, which coordinates charging/discharging based on battery state and grid conditions to optimize energy distribution. Although DES components are inherently non-linear, they are modelled using first-order lag transfer functions for simplicity and computational efficiency.

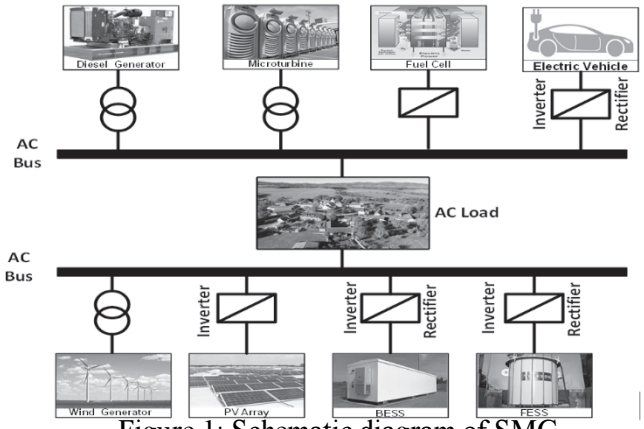


Figure 1: Schematic diagram of SMG

**Modelling of EV:** The EVs are equipped with batteries that can act as energy storage units when the vehicles are not in use. This reserved energy of batteries can used during the periods of high electricity demand or when RESs are underperforming. Through SoC-synchronized control, EVs can intelligently manage their charging and discharging operations in response to grid demands, thereby aiding in load management, and maintaining the balance between power supply and load demand. When EVs parked with a SoC above 80%, it can act as a BESS to support the grid during peak demand. The SoC model of EV used to calculate total charge/discharge power from controllable EVs

**Simulation Result and Discussions:** To validate the performance of the proposed integration of EVs, three different SMG operation scenarios have been considered. Scenario 1: Fluctuation of Wind power, Scenario 2: Fluctuation of Solar power and Scenario 3: Fluctuation of Load. All simulations were conducted using MATLAB/SIMULINK 2023 on a personal computer equipped with 6 GB of RAM and a 2.9 GHz Intel Core processor i5 processor.

**Conclusion:** This study presents frequency regulation of a SMG integrating EV with an SoC-based synchronous control and an MPA-optimized TID controller. The proposed approach is evaluated under wind, solar, and load disturbances and compared with PI, PID, PSO-, and WOA-tuned controllers. Simulation results confirm significant reductions in frequency deviation and settling time, improving SMG stability.

**Keywords—** Standalone microgrid, Load Frequency Control, Tilt Integral Derivative control, Marine Predator Algorithm, Electric Vehicle,

# OP-73: Design and development of network based smart electric vehicle charging schedule and management

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**Introduction:** Modern transportation systems are glorifying with the introduction of Electric Vehicles (EV), which are eco-friendly and do not produce harmful emissions. Each EV is equipped with a rechargeable battery, which can be charged with electricity. As fossil fuels are non-renewable energy resources, re-usage of such fuels is impractical and this situation makes EV an essential component in the future development of Intelligent Transportation Systems (ITS). However, due to rechargeable batteries, EV undergo certain challenges such as finding Recharging Terminals (RT), limited driving range, higher charging times, and expensive replacement of batteries. With the prevalence of green EV, the way to develop an efficient charge scheduling method to recharge while driving has become a significant problem . With recent advancements in communication technologies, an EV can send its fuel request efficiently to Road Side Units (RSU) or Base Stations (BS). Moreover, the progress time of the requests from EV is made simpler with the establishment of cloud computing technologies.

**Method and Materials:** The SEVC framework provides a charge scheduling management scheme for EV smartly and flexibly, leveraging SDN-assisted VEC. The FS algorithm trains the local and global models in VEC nodes and SDN, respectively. Only the model parameters are transmitted to the SDN rather than transferring raw data, thus minimizing overhead cost and processing time. An optimal electric charge scheduling strategy is introduced by considering charging availability and parking spot constraints. In the case of high-traffic regions, the availability of parking spots and plug-ins is taken into account. The SEVC schedules EV to RT to reduce travelling time and wait time of EV at RT. Also, to increase the overall user experience, an increment-based steady update method is used that does not allow constant changes in the scheduling process, as conditions in the environment are changing dynamically.

**Results and Discussion:** SEVC, an EV charge scheduling and management framework is proposed for optimizing charging schedules, finding the optimal routes from EV to RT, and predicting future demand for EV charging. The FS algorithm enables VEC nodes to train an optimal local model cooperatively and continuously. Optimal local models are then transmitted to SDN, where an optimal global model is trained.

**Conclusion:**

In this article, Software-Defined Networking (SDN)-assisted EV Charge (SEVC), an optimal charge scheduling strategy, is introduced to find appropriate Recharging Terminals (RT) for charging low-battery Electric Vehicles (EV). The Federated Support Vector Machine (FS) algorithm associates charge demanding EV with RT for getting an electric charge effectively. Furthermore, the FS algorithm predicts future charging demands of EV for adequate scheduling and future management. User constraints such as traveling, waiting, charging, and time loss in traffic are considered along with other constraints such as parking spots and charging spots available in RT to find out the optimal charging schedule.

**Keywords: EV, SDN, RT, SEVC**

# OP-74: Comprehensive Power Quality Assessment and Compensation in the IEEE 9-Bus System Using FACTS-Based Control

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**Introduction -** The increasing penetration of nonlinear and power-electronic-based loads in modern transmission networks has intensified power quality challenges, particularly harmonic distortion and voltage regulation issues. Harmonic currents generated by nonlinear devices propagate through interconnected networks, leading to voltage distortion, equipment overheating, and reduced system reliability. Maintaining compliance with IEEE 519 standards for total harmonic distortion (THD) has therefore become a critical requirement in contemporary power systems. The IEEE 9-bus test system serves as a widely accepted benchmark for evaluating transmission-level performance and control strategies. This research investigates harmonic distortion in the IEEE 9-bus system and proposes a STATCOM-based compensation approach to mitigate harmonic effects and improve voltage quality.

**Methods -** A steady-state IEEE 9-bus transmission model is developed in MATLAB/Simulink operating at 60 Hz with generators, transformers, transmission lines, and balanced loads. A nonlinear load modeled as a three-phase diode rectifier with a DC resistive load is connected at Bus 5 to introduce harmonic currents. Voltage waveforms and total harmonic distortion (THD) are measured using a Three-Phase V-I Measurement block and FFT analysis through powergui. A VSC-based STATCOM is integrated at the same bus to provide reactive power support, and system performance is evaluated before and after compensation.

**Result and Discussion -** Under base operating conditions, the IEEE 9-bus system maintains balanced sinusoidal voltages with THD within acceptable limits. The introduction of a nonlinear load increases harmonic injection, causing waveform distortion and elevating THD beyond the IEEE 519 limit of 5%. After integrating the STATCOM, reactive power support significantly improves voltage regulation and suppresses harmonic distortion. FFT analysis confirms that THD is reduced to IEEE 519 compliant levels, demonstrating the effectiveness of STATCOM-based compensation for harmonic mitigation in transmission networks.

**Conclusion -** This study evaluates harmonic distortion in the IEEE 9-bus transmission system and demonstrates that nonlinear loading significantly increases THD beyond IEEE 519 limits. The integration of a VSC-based STATCOM effectively suppresses harmonic distortion and restores voltage quality to compliant levels. The results confirm that STATCOM-based compensation provides a practical and scalable solution for transmission-level power quality enhancement.

**Keywords -** IEEE 9-Bus System, Power Quality, Harmonic Distortion, Total Harmonic Distortion (THD), IEEE 519, STATCOM, Reactive Power Compensation.

# PP-75: An Optimization Framework for Power Loss Minimization in a Distribution System Considering Electric Vehicle Charging Station Integration

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**Introduction:** The rapid growth in electric vehicle (EV) adoption is significantly increasing electricity demand in distribution networks, thereby introducing new operational and planning challenges. Among these challenges, the integration of electric vehicle charging stations (EVCSs) can lead to increased feeder loading, higher power losses, and voltage profile degradation if not properly planned. Distribution systems, which are traditionally designed for unidirectional power flow and relatively predictable load patterns, must now accommodate time-varying and location-dependent charging demands. Therefore, optimal siting and planning of EVCS infrastructure have become essential to maintain system efficiency and reliability. Power loss minimization is one of the key objectives in distribution system planning, as excessive losses not only reduce system efficiency but also increase operational costs. To address these challenges, optimization-based planning frameworks are increasingly being adopted. This study presents an optimization framework for minimizing power loss in a distribution system while considering EVCS integration under realistic daily loading conditions. The proposed work evaluates the impact of EVCS deployment on system performance and identifies suitable installation locations to mitigate adverse effects.

**Methods and Material:** The study is carried out on the IEEE 33-bus radial distribution test system. A direct approach load flow method is used to compute power flow and line losses under varying load conditions. To represent daily demand variation, 24 loading factor samples corresponding to 24 hours of the day are considered. Fixed-size EVCS units are integrated at three candidate locations, each capable of serving up to 50 EVs with a maximum charging rate of 20 kW per vehicle. A genetic algorithm (GA) is employed to determine optimal EVCS locations that minimize total system line losses.

**Result and Discussion:** Simulation results indicate that the integration of EVCS units increases the overall system loading, resulting in a rise in line losses. For the considered scenario, system losses increase by approximately 26.7% compared to the base case without EVCS integration. However, the application of the optimization framework significantly reduces the additional losses by identifying suitable installation locations that distribute load more effectively across the network. The analysis confirms that optimization plays a crucial role in mitigating the negative impacts of large-scale EV charging.

**Conclusion:** This study presents an optimization framework for minimizing power loss in a distribution system considering EVCS integration under time-varying load conditions. The results demonstrate that although EVCS deployment increases system losses, optimal placement can effectively limit these impacts. Future work may include coordinated charging strategies and the integration of distributed energy resources for further performance improvement.

**Keyword:** ***Electric Vehicle Charging Stations, Distribution System Planning, Power Loss Minimization, Genetic Algorithm***

## PP-76: POWER RESERVE CONTROL BASED MPPT OF SOLAR PV SYSTEMS IN DC MICROGRID

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**Introduction:** Solar photovoltaic (PV) energy sources are increasingly integrated in DC microgrids because of their high efficiency, modularity, and compatibility with DC loads and energy storage systems. Nevertheless, the intermittent and uncontrollable characteristics of solar generation introduce operational challenges, including DC bus overvoltage, battery overcharging, and unstable power flow during rapid irradiance fluctuations. MPPT-Based Power Reserve Control (MPPT-PRC) has emerged as an effective approach for achieving flexible, stable PV regulation with DC microgrids.

**Methods and Material:** The photovoltaic (PV) system alternates between maximum power mode and power reserve mode, facilitating periodic measurements of the maximum available power in maximum power mode. Perturb and observe method is used to achieve the maximum power point, which is implemented using MATLAB Simulink. Solar PV module, Boost converter, Bidirectional converter, DC load and, Battery energy storage system used as material.

**Result and Discussion:** In proposed method a solar photovoltaic (PV) source, battery energy storage system and a DC load, coordinated through a power management strategy. In the given system when solar irradiance is absent at that time battery energy storage system is providing power to the load. When surplus solar irradiance is present battery energy storage is consuming the power properly and maintaining bus voltage.

**Conclusion:** From above discussion and Simulink implementation it is concluded that solar PV-BESS system in DC microgrid is working properly and maintaining the DC bus voltage. Boost converter properly stepping up the input voltage to the desired value and bidirectional converter is properly doing work to charging and discharging battery energy storage system.

**Keyword:** ***PV, PRC, MPPT, BESS, Power Management***

# PP-77: Advanced Nanomaterial Design Strategies for High-Performance Supercapacitors based on Fractional Order Modeling

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**Introduction:** In contemporary energy storage systems, the low energy density and non-ideal electrical behavior of practical supercapacitors remain key obstacles for material design and integration. Despite their high-power density, fast charge–discharge rates, and long cycle life, performance is constrained by complex mechanisms such as electric double-layer storage, Faradaic reactions, interfacial polarization, and ion diffusion. These effects produce memory and dispersive dynamics beyond the capability of classical RC models. Fractional-order calculus offers a suitable framework to describe such behavior, motivating this study's unified modeling and stability analysis of epoxy-based supercapacitors incorporating MWCNT and MnO, /RuO, nanomaterials for improved efficiency and reliability.

**Methods and Materials:** The supercapacitor dielectric was prepared as a multifunctional nanocomposite of MWCNTs, MnO, /RuO, nanoparticles, and an epoxy matrix. MWCNTs created conductive percolation networks for efficient electron transport and distributed time constants, while metal-oxide nanoparticles provided pseudocapacitive storage through reversible surface redox reactions. The epoxy matrix ensured mechanical strength, thermal stability, and dielectric insulation while enhancing interfacial polarization.

**Result and Discussion**: The results indicate that increasing nanoparticle volume fraction reduces the fractional order á while increasing fractional capacitance Cá, demonstrating enhanced charge storage with stronger non-ideal behavior. Impedance plots show power-law frequency dependence, and phase responses remain nearly constant, confirming fractional-order characteristics. These findings reveal that nanostructured interfaces create distributed relaxation and memory effects. The relation $s^{\alpha}$+K=0 also verifies stable fractional dynamics, establishing the device as a true fractional-order supercapacitor.

**Conclusion:** This work presents a fractional-order modeling and stability framework for nanomaterial-based solid-state supercapacitors using MWCNT and metal-oxide nanocomposites. Results show that nanomaterials induce memory effects, interfacial polarization, and anomalous transport, producing high capacitance and constant-phase behavior. Fractional parameters á and Cá reflect physical processes, while Matignon-based analysis confirms wider stability regions, enabling reliable integration into advanced energy systems.

**Keywords:** ***Nanomaterials, fractional order, supercapacitor, stability analysis, energy storage.***

# OP-78: A VLC based LoS Underwater Communication System

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**Introduction:** The radio frequency (RF) and acoustic wave has been conventionally used for underwater wireless communication, but these systems face many issues like signal distortion due to turbulence, scattering, and attenuation. Use of visible light (VLC) for communication can be a promising technology for underwater communication because of its high speed at lower latency level, high bandwidth and immune to electromagnetic interference. In this work, an underwater VLC based line-of –sight (LoS) communication system has been designed, and the effect of environmental factors like scattering, absorption, and dynamic water properties has been studied. The simulated received power has been compared with the theoretical received power for an underwater VLC-LoS system**.** Also, the effect of receiver aperture diameter on received power has been analyzed. The maximum transmission ranges in different water types for underwater optical LoS communication haves been found.

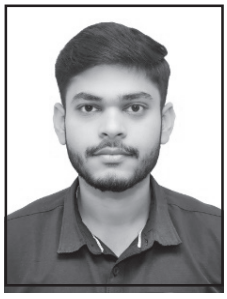
**Materials and Methods:** In this work an OptiSystem 22.0 simulator has been used to design a VLC based underwater LoS system. The underwater optical communication system consists of three main elements: the transmitter, the water as the channel, and the receiver. The transmitter consists of four main parts: (a) a user defined bit sequence generator; (b) NZR pulse generator; (c) the **light source i.e.** Laser Diodes (LDs); (d) a Mach-Zehnder **modulator**. The optical signal travels through an underwater medium. The optical receiver detects the optical signal and converts it to an electrical signal using an avalanche photodetector. After optical to electrical conversion the signal passes a low pass Bessel filter and the 3R regenerator, to restore the signal that has been transmitted over long distance.

**Results and Discussion:** The theoretical and simulated received power analysis considering each water type such as pure sea, clear ocean, costal ocean, harbor-I and harbor-II has been compared. Also the maximum transmission ranges for different water types having an input transmitter wavelength of 550 nm and transmitted power of 0 dBm have been found. The primary factor affecting the received power is the geometric spreading of the optical beam, but if the receiver's aperture is large enough to capture a significant portion of the expanding beam, the received power may still be acceptable. By keeping the transmitter aperture diameter at 5 cm, the effect of receiver aperture diameter having values of 20 cm, 5 cm, and 3 cm has been analyzed on the received power.

**Conclusion:** The theoretical and simulated received power analysis for each water type has been compared and found to be matching. The received power increases for short distance underwater communication. It has been found that when the receiver's aperture diameter is either the same as or smaller than the transmitter's, the power loss is minimum. Also, by keeping the receiver aperture diameter 5 cm and range 10 m, the received power is 0.315 mW which is nearly same as the transmitted power i.e. 0.383 mW. This work also compares the received power for an FSO and VLC based underwater LoS communication system.

**Keyword:** VLC, LoS, underwater communication, received power

# OP-79: ODEHA-Net: Optimized Deep Ensemble Framework with Hybrid Attention for Emotion Detection



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**Introduction:** Facial Expression Recognition (FER) plays a crucial role in affective computing, human-computer interaction, and behavioral analysis. However, existing methods often struggle with real-world challenges such as occlusions, pose variations, and subtle micro-expressions. To address these limitations, this study proposes ODEHA-Net, an Optimized Deep Ensemble Framework with Hybrid Attention, designed to achieve robust and interpretable emotion recognition.

**Methods and Material:** The proposed framework integrates complementary feature representations from both image-based and graph-based models via a late fusion strategy. The image-based branch utilizes a hybrid attention mechanism, combining spatial and channel attention to capture discriminative visual features. Simultaneously, the graph-based branch models structural dependencies among facial landmarks using a Graph Convolutional Network (GCN) with relational attention. The model was implemented using PyTorch on an NVIDIA RTX A6000 GPU, utilizing standard data augmentation techniques to enhance generalization.

**Result and Discussion:** Extensive experiments on benchmark datasets, including RAF-DB, AffectNet-7, and FERPlus, demonstrate that ODEHA-Net achieves state-of-the-art performance. The model achieved accuracies of 92.7% on RAF-DB, 65.4% on AffectNet-7, and 89.9% on FERPlus, outperforming representative CNN-based (ResNet18), Transformer-based (VIT-FER, Swin), and Mamba-based (MambaFER) models. Ablation studies validated the significant contributions of key components, specifically the Global Compact Attention Module (GCAM) and Hierarchical Feature Interaction Module (HFIM). The results highlight the model's superior adaptability to workload variations and robustness against occlusions.

**Conclusion:** This research demonstrates the effectiveness of integrating spatial and relational learning through ensemble architecture for FER. ODEHA-Net not only excels in accuracy but also maintains computational efficiency with 4.12M parameters, making it suitable for practical applications. Future research will focus on architectural enhancements to extend the framework for real-time emotion recognition in dynamic and unconstrained environments.

**Key words:** *Facial Expression Recognition (FER), Hybrid Attention, Graph Convolutional Networks (GCNs), Ensemble Learning, Deep Learning, Affective Computing.*

# OP-80: Learning-Based Ultra-Low-Power Optimization for VLSI Architectures

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**Introduction:** The increasing demand for ultra-low-power VLSI architectures in edge computing and IoT devices creates significant design challenges. Engineers must balance variables like voltage scaling and clock gating against process variation and thermal constraints, which traditional optimization methods often fail to manage in real time. This work addresses these issues through a framework that treats VLSI design as a sequential decision-making process. By employing Deep Reinforcement Learning (DRL) to adaptively manage voltage levels, clock frequencies, and workload scheduling, the system effectively navigates complex design trade-offs. Experimental results demonstrate that this methodology achieves over a 22% power reduction compared to standard Dynamic Voltage and Frequency Scaling (DVFS) techniques, providing a scalable and robust solution for modern electronic systems.

**Methods and Material:** Optimizing ultra-low-power VLSI architectures is a critical challenge in modern hardware design. While traditional techniques like DVFS are standard, they often struggle with the dynamic variability of system workloads. To address these limitations, this research proposes a framework that models VLSI design as a Markov Decision Process using Proximal Policy Optimization (PPO). At the core of this approach is a trained agent that evaluates nine system parameters to adaptively adjust scaling and gating. This methodology achieves a 20–25% power reduction over conventional approaches, ensuring efficient real-time performance.

**Result and Discussion**: Unlike static DVFS methods, the proposed PPO-based framework dynamically adapts to workload variations, achieving a 22.4% reduction in power consumption. Comprehensive simulations on the 22 nm FD-SOI process node demonstrate the superiority of reinforcement learning in balancing energy efficiency and thermal constraints. By integrating real-time scaling and gating decisions, this methodology advances sustainable VLSI design for edge computing. Experimental results over 500 training episodes confirm that the agent effectively manages complex trade-offs, providing a robust, scalable alternative to conventional heuristic-based power management units in modern electronic systems.

**Conclusion:** This research demonstrates that Proximal Policy Optimization effectively manages power-performance trade-offs in VLSI designs. Modeling the system as a Markov Decision Process, the framework achieved 22.4% power savings over conventional DVFS on a 22 nm FD-SOI node. By adaptively navigating workload variability and thermal constraints, this methodology provides a robust, scalable solution for ultra-low-power architectures, ensuring high energy efficiency without compromising the performance of modern IoT devices.

**Keyword:** ***Deep Reinforcement Learning, VLSI Power Optimization, Proximal Policy Optimization, Ultra-Low-Power Design, Dynamic Voltage and Frequency Scaling (DVFS)***

# OP-81: Implementation of High-Speed and Low Power Modified Vedic Multiplier Using Hybrid Adders

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**Introduction:** Arithmetic multiplication is a foundational process in modern processors, particularly for tasks requiring high computational density. The overall effectiveness of these systems is heavily influenced by the multiplier's efficiency, which is typically assessed based on its silicon footprint, power usage, and signal propagation time. Emerging non-traditional computing paradigms, which move away from standard CMOS-based von Neumann models, necessitate the development of high-speed arithmetic units to manage complex signal processing. Vedic multipliers, based on ancient mathematical principles, have become a focal point of research due to their potential for high-speed operations using efficient adder structures.

**Methods and Material:** This study presents a 32-bit modified Vedic multiplier that leverages the "Urdhva Tiryakbhyam" algorithm for vertical and crosswise multiplication. A key innovation in this architecture is the insertion of a '0' at the final addition stage following carry propagation to optimize performance. The design employs a 32-bit hybrid adder composed of alternating 4-bit Carry Save Adder (CSA) and Carry Look-Ahead Adder (CLA) blocks. The multiplier has been developed using Verilog HDL at the gate level, functional verification through simulation using Cadence using 180nm ASIC technology library. Further, hardware implementation has been done on a Zynq-7000 SoC (ZedBoard) FPGA.

**Result and Discussion**: The proposed hybrid-adder-based multiplier shows substantial performance gains over conventional reversible 32-bit multipliers. Experimental results indicate a total power consumption of 6909.828nW and a low propagation delay of 4.839ns. When compared to CSA-based reversible architectures, the modified design achieved reductions of 97.68% in Power-Delay Product (PDP), 26.64% in Area-Delay Product (ADP), and 97.01% in Power-Area-Delay Product (PADP). While the total area of 3741ìm$^2$ is higher than some reversible counterparts, the improvements in energy efficiency and speed are significant.

**Conclusion:** The implementation of a 32-bit modified Vedic multiplier using hybrid adders successfully balances the trade-offs between speed and power. Its superior energy efficiency and low latency make it an excellent candidate for high-performance digital signal processing units. Future work could focus on further optimizing the silicon area while maintaining these power and delay advantages for use in energy-constrained computing environments.

**Keyword:** Modified Vedic Multiplier, Hybrid Adder, Energy-Efficiency, High-Speed Computing, VLSI Design, Power-Delay Product

# OP-82: Analysis of Cement ageing effects using fractional order modelling

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**Introduction:** Cement, a vital material in the construction industry, plays a crucial role in ensuring the structural integrity and longevity of buildings and infrastructure. The adulteration of cement significantly compromises the structural integrity and durability of buildings and infrastructure, as it reduces the cement's bonding strength, density, and overall performance. The fractional inductor, a key component, is designed to exhibit fractional-order impedance characteristics, which are highly sensitive to changes in the material properties of cement. When the inductor generates an electromagnetic field, the cement sample interacts with this field, and its impedance response varies based on its composition, structure, and age.

**Methods and Materials:** The proposed cement expiry and adulteration sensor operates on the principle of fractional inductance. A transverse electromagnetic (TEM) model with a conducting core demonstrates a fractional inductance of half-order, specifically á=0.5. On the other hand, the orders drop down from 0.5 upon incorporating semiconducting particles as the core. When cement is used as the core material in a transverse electromagnetic mode (TEM) of Co-axial structure, it has been analyzed that its parasitic capacitance and resistance is very low, often negligible, due to its inherent material and structural properties.

**Result and Discussion**: Different cement samples of 1 month, 3 months, 6 months, and 8 months from the date of manufacture have been examined as the core of the TEM model. The frequency domain analysis with these cores is conducted experimentally, and the magnitude and phase plots are shown in Fig.1.It has been observed that the phase and roll-off rate of the inductive element increase when the time frame of the cement gets older, increasing the value of á.

**Conclusion:** Experimental observations reveal that a clear decline in fractional inductance with increasing expiry index, signifying the progressive deterioration of the cement's dielectric and conductive properties. Initially, the inductance remains relatively high, indicating minimal material degradation. However, as the aging increases from 1 to 8 months, the inductance drops considerably, reflecting changes in the cement's micro-structure, such as increased porosity and possible moisture infiltration. These in effective permeability and permittivity, ultimately affecting the inductive response. Frequency-domain analysis across a wide range (5 kHz to 5 MHz) allows for identification of these property changes, particularly under high-frequency excitation.

**Keywords:** ***Fractional inductor, TEM, inductive sensor, cement adulteration, cement expiry.***

# OP-83: Fractional-Order Capacitive Modelling of Fruit Bio-Impedance for Dispersive Behaviour Analysis

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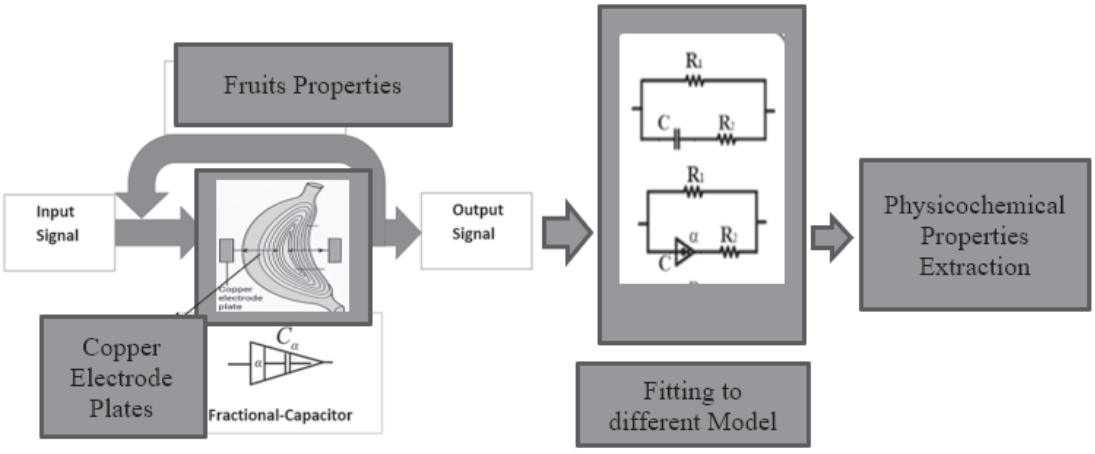
**Introduction:** Electrical characterization of fruits is a non-destructive technique for assessing quality and freshness. Due to tissue heterogeneity, fruit bioimpedance exhibits complex, dispersive behaviour under alternating current excitation. Conventional integer-order models assuming ideal capacitance often fail to capture these dynamics. Fractional-order modelling effectively represents non-ideal capacitive behaviour using distributed electrical parameters. Experimental bio-impedance analysis over 200 Hz–200 MHz confirms that fractional-order models, the Fractional order modelling, provide superior fitting accuracy.

**Methods and Materials:**




**Result and Discussion**: The impedance spectra of fruit tissues exhibit pronounced dispersive behaviour, with frequency-dependent magnitude and non-ideal phase responses that are poorly captured by integer-order models. Fractional-order capacitive modelling accurately represents both magnitude and phase characteristics through a constant phase element, reflecting distributed relaxation mechanisms. The extracted fractional parameters remain stable across different frequency ranges, confirming the robustness and physical relevance of the fractional-order representation over conventional models.

**Conclusion:** This study demonstrates that fruit bio-impedance exhibits non-ideal capacitive behaviors that can be effectively represented using a fractional-order capacitive model. The fractional-order framework outperforms conventional integer-order formulations while maintaining low model complexity and stable parameter estimation. The results highlight the suitability of fractional-order modelling as a reliable tool for non-destructive fruit sensing and quality evaluation, with potential for integration into practical agricultural monitoring systems.

**Keyword:** ***Fruit bio-impedance, Fractional-order modelling, Constant phase element, Non-destructive sensing, Agricultural quality assessment***

# OP-84: Secure Edge-AI on PLC-Integrated Embedded Controllers for Predictive Maintenance in Smart Manufacturing

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**Introduction:** Modern smart manufacturing environments require deterministic control, low ps response time of fault detection and hardware low level reliability. Conventional predictive maintenance systems that utilize a lot of cloud computing experience latency, cyber security exposure and network dependency. This work introduces the hardware-centric predictive maintenance approach using the integration of industrial programmable logic controllers (PLC) and an ARM based embedded controller to monitor machines in a secure way in real-time.

**Materials and Methods:** The system uses vibration sensors (IEPE-based), resistance temperature detectors (RTDs) and current sensors (Hall effect), have been interfaced to a PLC using analog input modules that comply with 4-20 mA standard and 0-10 V standards. The PLC is communicating using Modbus TCP with an ARM Cortex A based embedded controller with a hardware crypto engine and on-board ADC/DMA support. Signal conditioning circuits to include instrumentation amplifiers, anti-aliasing filters and isolated power to achieve industrial immunity from noise. A light-weight embedded inference engine means that the fault classification is performed local. To ensure the safe transmission of data, hardware-based TLS over Ethernet is used. Deterministic Relays and Motor Drive Control from the PLC logic outputs directly, the generated signals trigger relay and motor drive to control as soon as they have detected the anomaly.

**Results and Discussion:** The hardware validation under induced bearing defects and load imbalance condition successfully performed the real time working with a total system latency time <18 ms. The isolated signal conditioning stage helps in getting better noise rejection by 32% compared to direct interfacing of the sensor. Edge processing helps reduce the external traffic by 60 per cent and thus minimises the industrial cybersecurity threats. The PLC based integration guarantees a deterministic actuation with zero packet loss event during 72 hours non-stop test condition. The hardware platform has a suitability for harsh industrial environments.

**Conclusion:** The developed PLC - integrated embedded architecture is a solid and secure hardware framework for predictive maintenance for smart manufacturing. By incorporating intelligence into industrial controls, with the support of secure communication modules the system also increases reliability, reduces downtime and supports scalable implementation of Industry 4.0. Research to be done is to be integrated with FPGA-based accelerator and hardware root of trust modules.

**Keyword:** PLC Integration Controllers, Embedded controllers, Predictive maintenance, Industrial Sensor, Edge Hardware, Smart Manufacturing.

# OP-85: Fault Tolerant Control design using metaheuristic methods for non-linear time delay process

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**Introduction:** Heat exchangers are vital components in chemical, power generation, refrigeration, and process industries where efficient thermal energy transfer between fluid streams is required. Maintaining the desired outlet temperature is essential for ensuring product quality, process safety, and energy efficiency. However, heat exchanger systems exhibit nonlinear dynamics due to varying flow rates, temperature-dependent properties, and heat transfer coefficients. In addition, practical operation is affected by disturbances, parameter uncertainties, fouling, and potential faults in sensors and actuators. Such faults may degrade control performance, increase steady-state error, and in severe cases, lead to unsafe operating conditions. Therefore, the development of a reliable fault-tolerant control (FTC) strategy is necessary to maintain system stability and performance even in the presence of faults.

This study presents the design and comparative evaluation of fault-tolerant control strategies for a nonlinear heat exchanger process using Proportional–Integral–Derivative (PID) and Fractional-Order PID (FOPID) controllers. The objective is to analyze their performance under both normal and faulty operating conditions and to assess their robustness against disturbances and parameter variations.

**Materials and Methods:** Fault conditions such as sensor bias faults and actuator gain reduction are introduced into the simulation to evaluate controller robustness. Controller design and performance analysis are carried out in the MATLAB/ Simulink environment. A classical PID controller is first designed and tuned to achieve acceptable setpoint tracking and disturbance rejection under nominal operating conditions. The PID controller serves as a baseline for comparison.

Subsequently, a Fractional-Order PID (FOPID) controller is implemented. Fractional integral and derivative orders enable more precise adjustment of system dynamics and improved robustness against uncertainties and faults.

The performance of both controllers is evaluated using standard time-domain specifications such as rise time, settling time, overshoot, and steady-state error. Integral performance indices including Integral Absolute Error (IAE) and Integral Square Error (ISE) are also used to quantify control accuracy.

**Results and Discussion:** Simulation results demonstrate that under normal operating conditions, both PID and FOPID controllers achieve satisfactory temperature tracking. However, the FOPID controller exhibits improved transient performance characterized by reduced overshoot and faster settling time compared to the conventional PID controller.

Under fault conditions, the performance difference becomes more significant. When a sensor bias fault or actuator degradation is introduced, the PID controller shows noticeable performance deterioration, including increased steady-state error and slower disturbance rejection. In contrast, the FOPID controller maintains closer tracking of the desired temperature and demonstrates enhanced resilience to faults. The integral performance indices further confirm that the FOPID controller achieves lower error values, indicating superior robustness and fault accommodation capability.

**Conclusion:** The comparative analysis confirms that while the classical PID controller provides satisfactory baseline performance, the FOPID controller offers enhanced robustness, improved transient response, and better fault-tolerant characteristics for nonlinear heat exchanger systems. The additional flexibility provided by fractional-order parameters enables improved handling of nonlinearities, disturbances, and fault scenarios. These results highlight the potential of fractional-order control strategies in enhancing reliability and performance in industrial thermal processes.

# OP-86: Implementation of Linear equalization and Decision feedback equalization for signal detection in OWC system under OOK, DPSK, PPM modulation Schemes

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**Introduction:** Optical Wireless Communication (OWC) channel has been demonstrated to be a very good alternative to the Radio Frequency (RF) channel. The high data rate transmission capability and reliable connectivity makes it suitable to support the IoT requirements. There are some unavoidable drawbacks associated with the OWC channel in different environments. In this work, two unavoidable problems in an indoor OWC channel have been discussed, one is known as ambient light interference and another is multipath delay. To mitigate the influence of these contaminations in the received signal and enhance the signal quality Matched filter (MF) and Artificial Neural Network (ANN) based equalization techniques have been used.

**Methods and Material:** This work proposes a unified ANN-based linear and decision feedback equalization framework incorporating matched filtering and realistic ambient light interference with multipath delay modeling. The proposed approach enables a comprehensive BER comparison across multiple modulation schemes, providing deeper insights into the trade-offs between complexity, robustness, and performance in indoor optical wireless communication systems. The OOK, DPSK and PPM modulation schemes were investigated under the scenario along with two different equalization techniques, such as ANN-Linear equalizer and ANN- DF equalizer. The performance outcome is compared with that of the previous schemes.

**Result and Discussion**: Considering the BER curve the PPM based DF equalization shows the best performance by achieving a minimum value of the order of $10^{-5}$ BER at an SNR of 23 dB. If we compare the equalization techniques, for each modulation schemes the BER curves comes better for DF-equalization. If we compare the modulation schemes, among the three, PPM shows best result.

**Conclusion**:

This work represents a comparative study of two different ANN based equalization techniques in enhancement of the quality of performance of an OWC system for indoor environment. It also considers the importance of choice of modulation scheme for a particular scenario to achieve a minimum BER. The combination of PPM modulation scheme along with ANN based DFE gives best result as compare to other system studied in this work.

**Keywords—** ***OWC, DPSK, PPM, ANN-DF equalizer, ANN- linear equalizer, AWGN, ambient light***

# OP-87: Hybrid Homotopy-Stochastic Optimization for Phase-Constrained Broadening in Uniform Planar Arrays

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**Introduction:** Modern multifunction phased array radar systems often produce narrow high-directivity beams, which limit angular coverage and increase search frame time in wide-area surveillance applications. In solid-state active phased arrays, transmit amplifiers typically operate in saturation, making amplitude control impractical and thereby necessitating phase-only pattern synthesis (POPS) for beam shaping. The phase-only synthesis problem is inherently nonlinear and highly non-convex, making direct optimization challenging for large-scale arrays. Beam broadening through phase-only control offers a hardware-compatible and power-efficient approach to increase spatial coverage without altering array size or transmit power. This study presents a hybrid optimization framework for controlled wide-beam synthesis in uniform planar antenna arrays while maintaining acceptable sidelobe levels and beam efficiency.

**Materials and Methods:** A 16 × 16 Uniform Planar Array (UPA) with half-wavelength inter-element spacing was modelled in MATLAB. The radiation pattern was computed using array factor formulation in elevation and azimuth domains. Beam broadening was achieved by optimizing element phase excitations while keeping amplitudes constant. A hybrid optimization strategy combining Homotopy Continuation and Stochastic Gradient Descent (SGD) was implemented. Homotopy gradually transformed the objective function from a narrow-beam configuration to a broadened target profile, ensuring stable convergence in a non-convex solution space. SGD enabled computationally efficient iterative phase refinement through stochastic gradient updates. Beamwidth ("3 dB criterion), sidelobe behaviour, objective convergence, and broadening ratio were quantitatively evaluated and comparative analysis was performed against the unoptimized configuration.

**Results and Discussion:** Simulation results demonstrate significant beamwidth enhancement in both elevation and azimuth domains. The total beamwidth increased from 6.34° (unoptimized) to 69.31°, while azimuth beamwidth expanded from 6.34° to 130.41°, achieving broadening ratios exceeding 10× and 20× respectively. Convergence analysis confirmed smooth reduction of the objective function under homotopy-guided optimization across iterative continuation steps. Although beam broadening resulted in a moderate reduction in peak gain and slight sidelobe elevation, the widened main lobe provided substantially improved angular coverage. The results further demonstrate controlled redistribution of radiated energy within the broadened main lobe region, highlighting the capability of phase-only optimization to balance beamwidth expansion and sidelobe containment.

**Conclusion:** This work validates that phase-only beam broadening using a hybrid Homotopy–SGD optimization framework provides a stable, scalable, and hardware-compatible solution for extreme beam shaping in phased array systems. The proposed approach enables controlled beam spoiling while preserving hardware simplicity, making it well suited for solid-state radar architectures. The results demonstrate that significant beamwidth enhancement can be achieved using phase-only control without additional amplitude modulation. The methodology supports wide-area search operations, adaptive surveillance, and multifunction radar systems where enhanced angular coverage is critical.

**Keywords:** *Phase-only pattern synthesis, Beam broadening, Phased array radar, Homotopy continuation, Stochastic gradient descent, Uniform planar array, Beam efficiency*

# OP-88: Underwater Image Enhancement Using Adaptive Multi-Scale Contour Bougie Morphology with Semantic Red Recovery

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**Introduction:** This work presents an underwater image enhancement framework using adaptive multi-scale contour bougie morphology with semantic red recovery (AMCBM-SRR), optimizing structural and chromatic restoration. The proposed approach includes foreground-aware enhancement and statistically controlled red-channel compensation-based recovery. The study demonstrates improved visual quality under severe underwater degradation and includes extensive evaluation using standard underwater image datasets and objective quality metrics.

**Materials and Methods**: The proposed framework follows a structured enhancement pipeline to improve underwater image clarity and color balance. Region-aware processing is first performed to separate important structural areas from background regions. Adaptive multi-scale contour bougie morphology restores scattering-degraded boundaries, followed by controlled red-channel and contrast enhancement. Performance is evaluated on benchmark datasets using UCIQE, UIQM, and PCQI with fixed-iteration processing for stable results. Visual and quantitative comparisons showing improved clarity, contrast, and color fidelity are presented below.

**Results and Discussion:**


**Figure 1.** Visual comparison on a submerged statue scene. From left to right: original image, CBM, and AMCBM-SRR.

Figure 1 shows the visual comparison on a submerged statue scene. While CBM improves visibility and contrast over the original image, the proposed AMCBM-SRR provides clearer structural details, better red-channel restoration, and more natural color correction. The average quantitative results on the UIEBD dataset show that AMCBM-SRR achieves the highest performance across all evaluation metrics, with UCIQE = 0.623, UIQM = 2.95, and PCQI = 0.56. It significantly outperforms HE, CLAHE, and CBM, clearly demonstrating its superior image enhancement capability and effectiveness in improving underwater image quality.

**Conclusion:** The proposed AMCBM-SRR framework enhances underwater images by improving structural clarity, color fidelity, and contrast under severe degradation conditions. It integrates multi-scale contour restoration with controlled red-channel recovery to achieve superior visual quality and computational efficiency, making it suitable for underwater vision and navigation applications.

**Keywords**: Underwater Image Enhancement, Multi-Scale Morphology, Semantic Red Recovery, Underwater Image Quality Measure (UIQM), Underwater Color Image Quality Evaluation.

# OP-89: A Secure, Edge-Intelligence Framework for Predictive Maintenance in Industry 4.0: Integrating XAI and Uncertainty Quantification

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**Introduction:** As industrial systems evolve into complex Cyber-Physical Systems (CPS), traditional maintenance models struggle with the convergence of Operational Technology (OT) and Information Technology (IT). While Industrial IoT (IIoT) facilitates predictive maintenance (PdM), challenges persist regarding network latency, data privacy, and the inherent "opacity" of deep learning models. This research proposes an advanced framework that decentralizes intelligence to the Edge to ensure real-time response while maintaining a robust security posture.

**Materials and Methods**: The methodology utilizes a high-fidelity data acquisition system for machine health monitoring, capturing spatial and temporal features through deep learning architectures. To bridge the trust gap, the framework integrates Explainable AI (XAI) using a unified interpretation approach (SHAP/LIME) to provide human-readable insights into model decisions. Crucially, this phase introduces Uncertainty Quantification (UQ) to the predictive pipeline, allowing the system to communicate its confidence levels for each maintenance alert, thereby reducing false positives. The security architecture is grounded in NIST-aligned OT security guidelines and Generative AI-driven Zero Trust principles to safeguard against sophisticated cyber-attacks.

**Results and Discussion**: Preliminary evaluations show that the Edge-AI deployment reduces data transmission latency by approximately 40%, which is critical for time-sensitive industrial automation. The integration of Neural Network models with UQ capabilities maintains a high fault detection accuracy of 90%, while identifying "out-of-distribution" data that could lead to erroneous predictions. Comparative analysis confirms that the proposed XAI-driven transparency significantly improves operator trust compared to "black-box" models. Furthermore, simulation data suggests that the combined framework can reduce unplanned downtime by up to 30%, optimizing maintenance schedules and yielding substantial cost efficiencies.

**Conclusion/Recommendation:** The research concludes that a holistic approach—combining Edge-Intelligence, XAI, and robust OT security—is vital for the secure digital transformation of industrial sectors. By providing a scalable blueprint that accounts for model uncertainty, this framework ensures both operational resilience and cybersecurity. Future work will focus on investigating the interoperability of this framework with evolving global 5G/6G standards for ultra-reliable low-latency communication.

**Key words**: Edge AI; Explainable AI (XAI); Uncertainty Quantification; OT Security; Cyber-Physical Systems (CPS)

# OP-90: Non-2^N Depth Asynchronous FIFO Design: A Power and Area Efficient Approach

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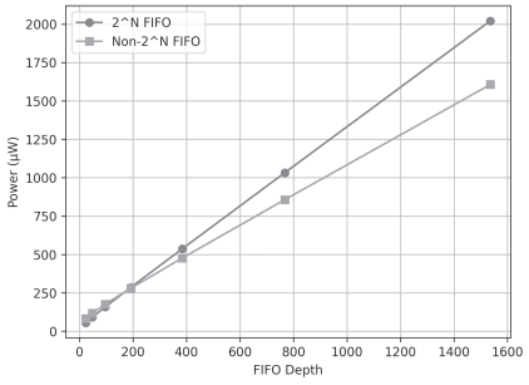
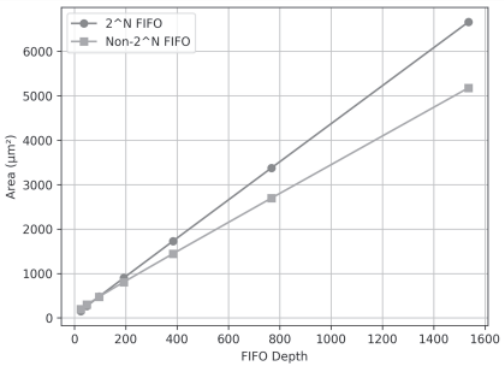
**Introduction:** When there are multiple clock domains in a design or interface with real world scenarios, the communication between devices is always asynchronous. In modern day digital design for SoC (System-on-Chip) and FPGAs, asynchronous FIFO enables the reliable communication between independent clock domains or asynchronous domains. Standard asynchronous FIFO designs involve the power-of-two depths structures. This simplifies the read and write pointer wrapping and full/empty calculation logic. However, in reality, the required FIFO depths are dependent on the communication protocol, latency requirement and storage/buffer requirement. If the required size is not 2^N, then it forces the designers to use the next higher power-of-two depth. This results in extra memory entries which are never accessed, increased leakage and dynamic power and larger silicon area. This work proposes a non-$2^N$ depth asynchronous FIFO architecture that eliminates extra memory padding while maintaining CDC safe.

**Materials and Methods:** The proposed architecture makes changes in in the conventional asynchronous FIFO structure with respect to Pointer wrap logic, Full detection mechanism, Pointer comparison strategy. Technology node used 28nm.

**Results and Discussion: Comparison of power and area for 2^N and non-2^N depth async FIFOs**




*Total Power Saving = 16-25% , Break-even depth is 64 to 96.*

**Conclusion:** This work presents a non-2^N depth asynchronous FIFO architecture that eliminates the constraints of power-of-two depth requirements in the conventional design of asynchronous FIFOs. The proposed approach does the storage memory sizing while keeping the CDC safe and reliable. For a 28nm technology node, there is an **area and power reduction** of **16–25** for medium and large FIFOs in SoC subsystems and large storage applications in asynchronous domains.

**Keywords:** SoC, FIFO, CDC, pointers, asynchronous, subsystems

# OP-91 : Polarization Diverse Dual band Metasurface inspired Wearable antenna for Reliable 2.45/5.8 GHz Body-centric Communications

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**Introduction:** Antenna must operate steadily close to human body for Wireless Body Area Network (WBAN) applications. Conventional antenna suffers from reduced performance and high Specific absorption Rate (SAR) close to human body whereas Artificial Magnetic Conductor (AMC) integrated with antenna provides better antenna performance, low SAR value by minimizing the back body radiation. Dual band at 2.45 GHz and 5.8 GHz supports modern wireless standard while circular polarization improves communication reliability during body motion. Therefore, integrating a dual band antenna with Polarization converting metasurface offers a compact and efficient solution for high performance body centric communications.

**Materials and Methods:** A compact dual band antenna with felt substrate is designed to operate at 2.45 GHz and 5.8GHz. A polarization converting metasurface (PCM) is designed using transmission line model and optimized to have dual band characteristics at both the frequency. In order to achieve higher antenna performance, the dual band is integrated with the 2×2 AMC metasurface. Full wave simulations are performed to analyse the S11, gain, axial ratio and SAR parameters by keeping the whole antenna near a human body model.

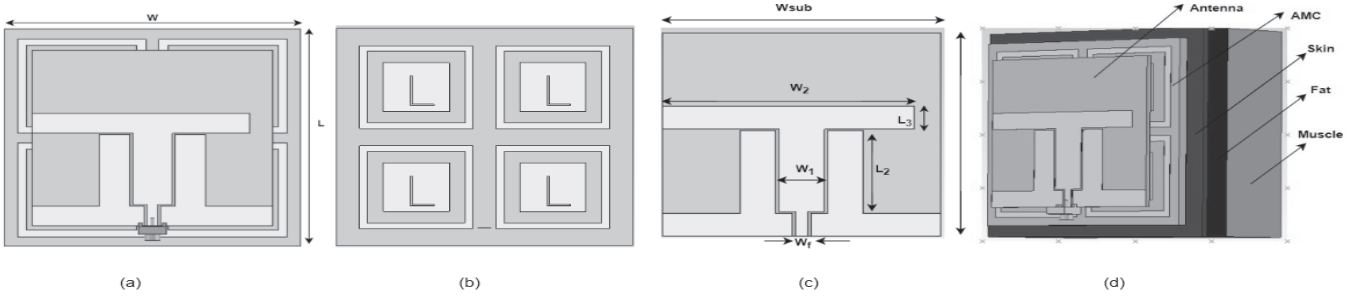


Fig 1: (a) Dual Band Patch Antenna (b) 2×2 AMC (c) Dual band antenna Integrated with AMC (d) Antenna with AMC on Human body

**Results and Discussions:** The AMC integrated antenna has higher impedance bandwidth of 1750 MHz at 5.8 GHz. The realized gain increases to 5.1 dBi at 2.45 GHz and 7.89 dBi at 5.8 GHz, showing strong forward radiation than conventional patch antenna. The axial ratio graph shows that the AMC integrated antenna is exhibiting circular polarization at 5.8 GHz where as linear polarization at 2.45 GHz. The farfield radiation pattern shows weak LHCP and strong RHCP component at 5.8 GHz. When the AMC integrated antenna is placed close to the human body, it shows a reduced SAR values of 0.214 W/Kg over 10 g of tissue at 2.45 GHz where as 0.12 W/Kg over 10 g of tissue at 5.8 GHz. These values are lower than the international safety limit indicating a good wearable antenna for WBAN applications.

**Conclusions:** The proposed AMC based antenna resonates at dual frequency band of 2.45 GHz and 5.8 GHz. The gain is improved to 5.1 dBi and 7.89 dBi at both frequency band. The ultra-low SAR value of 0.214 W/Kg and 0.12 W/Kg over 10 g of tissue at 2.45 GHz and 5.8 GHz respectively show that the proposed antenna can be good candidate for wearable antenna for WBAN applications.

**Keywords:** Dual band, Circular Polarization, SAR, Artificial magnetic conductor, WBAN

# OP-92: Comparative Analysis of Enzyme Inhibition Effects on Amperometric Biosensor Performance in Biomedical Applications

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**Introduction:** Amperometric biosensors play a crucial role in biomedical diagnostics for monitoring clinically significant biomarkers such as glucose, lactate, and cholesterol. However, under physiological and pathological conditions, enzyme inhibition mechanisms can significantly alter sensor response and compromise diagnostic accuracy. This study presents a comparative mathematical analysis of enzyme inhibition effects on amperometric biosensor performance. A steady-state reaction–diffusion model incorporating Michaelis–Menten kinetics, substrate inhibition, and uncompetitive inhibition was developed and solved numerically using MATLAB's boundary value solver. The results demonstrate that inhibition mechanisms reduce current response, decrease sensitivity, and narrow the linear detection range. Substrate inhibition predominantly affects high analyte concentrations, while uncompetitive inhibition causes uniform signal attenuation. The findings highlight the necessity of incorporating inhibition mechanisms into biosensor modeling, calibration, and biomedical interpretation to enhance diagnostic reliability.

**Methods**: A steady-state reaction–diffusion model was developed to describe substrate transport and enzymatic reaction within the biosensor enzyme layer. The governing equation is:

$$D_s \frac{d^2S}{dx^2} - v(S) = 0$$

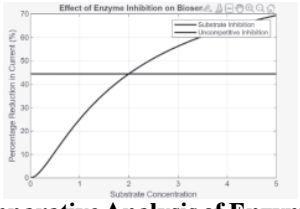
where: $D_s$is the substrate diffusion coefficient, $S$is the substrate concentration, $v(S)$represents the enzymatic reaction rate.

Three kinetic models were incorporated:

1. Michaelis–Menten (No Inhibition): $v = \frac{V_{max}S}{K_m+S}$
2. Substrate Inhibition $v = \frac{V_{max}S}{K_m+S+\frac{S^2}{K_s}}$
3. Uncompetitive Inhibition $v = \frac{V_{max}S}{(K_m+S)(1+I/K_i)}$

The nonlinear second-order differential equation was transformed into a system of first-order equations and solved numerically using MATLAB's BVP4C solver. Steady-state current was calculated from the substrate gradient at the electrode surface.

**Results and Discussion:**



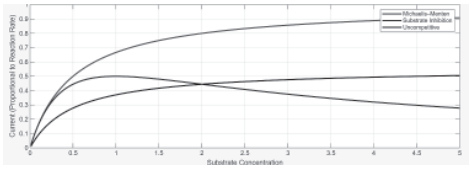




**Fig. 1 Comparative Analysis of Enzyme Inhibition Effects** **Fig. 2 Effect of Enzyme Inhibition on Biosensor Current**

The results show that enzyme inhibition reduces current response and sensitivity compared to ideal Michaelis–Menten behaviour. Substrate inhibition mainly affects high concentrations, while uncompetitive inhibition causes overall signal reduction, impacting biosensor accuracy in biomedical applications.

**Conclusion:** This study shows that enzyme inhibition reduces current, sensitivity, and linear range compared to ideal Michaelis–Menten kinetics. Accounting for inhibition effects is essential for accurate and reliable biomedical biosensor performance.

**Keywords:** Amperometric biosensor, Enzyme inhibition, Michaelis–Menten kinetics, Substrate inhibition

# OP-93: An Intelligent Path Selection and Resource Allocation in Multi hop D2D Communication

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**Introduction:** As the exponential growth of internet users rises day to day it demands the high speed data rate for application such as video streaming, online gaming, Industry 4.0 and Iot based applications. This demand creates a solution such as Multi hop Device to Device communication, which is a promising solution to enhance throughput for high speed data traffic. It enables the direct communication between two nearby devices without travelling through the base station. The proper optimization of available spectrum increases the spectral efficiency and reduces traffic congestion at the base station. To meet this requirement, we have come up with two intelligent algorithms using reinforcement learning for path selection and as well as resource allocation.

**Methods and Material:** Here, we propose two reinforcement learning optimization techniques for path selection and resource allocation. We propose a multi objective reward function based Q learning for multi hop path selection. Where Euclidean distance is used to minimize hop length, Signal to Interference plus Noise Ratio (SINR) is used to ensure link reliability and residual energy is used to enhance network lifetime. We combined all the three parameters to constitute our reward function. In part II we proposed a hybrid Proximal Policy Optimization and Ant Colony Optimization together to optimize resource allocation. This optimization technique enhances the throughput in Gbps range. Two different reinforcement learning algorithm, Q learning and PPO are used here to address path selection and resource allocation respectively.

**Results and Discussion:** Simulation results show that proposed multi objective Q algorithm reduces computational time compared to conventional routing algorithms. It achieves approximately 82% lower computation time than Dijkstra and A* algorithm. This result shows the efficiency of reinforcement learning path discovery process in D2D environments. Furthermore, the proposed Hybrid PPO ACO resource allocation scheme achieves better throughput compared to existing optimization techniques such as PSO, GWO, Hybrid PSOGWO, ACO and PPO. It enhances spectrum efficiency and achieves the desirable data rate. The joint optimization of intelligent algorithms lead to significant improvements in overall system throughput and network performance.

**Conclusion:** This work presents an two stage reinforcement learning framework for enhancing throughput in D2D communication. The proposed multi objective Q algorithm SINR aware multi hop path selection with substantially reduced computation time. The Hybrid PPO ACO algorithm further maximizes throughput by optimized resource block allocation. Simulation results confirm that the integrated framework outperforms conventional routing and resource allocation methods in terms of computational efficiency and throughput. The proposed approach provides a scalable and intelligent solution for next generation high capacity, low latency wireless networks.

**Key words:** *D2D, multi hop, Q learning, Reinforcement Learning, Throughput*

# PP-94: Nature Inspired Hybrid Optimization Algorithm for Resource Block Allocation in D2D Communication

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**Introduction:** The rapid increase in wireless data traffic, driven by the wide use of smart devices and bandwidth intensive application, has created a significant challenges for nest gen wireless networks. Modern system are now required to deliver higher spectrum efficiency, enhanced power control and improved overall throughput. In this context, Device to Device communication has now emerged as a potential solution. D2D communication improves spectral efficiency, reduce latency and traffic burden on network by enabling direct communication between nearby devices without routing through the base station. Traditional resource allocation techniques often struggle due to the highly non linear and complex nature of interference. In addition to this, as density of devices are increasing, the scalability is also concerning, leading to the need for more flexible and intelligence optimization techniques.

**Methods and Materials:** In this work, we focus on optimizing resource block allocation in D2D communication by proposing a nature inspired hybrid algorithm, namely HPSOWOA (Hybrid PSO-WOA). The primary objective is to improve system performance by achieving an effective balance between the strengths of the two algorithms. HPSOWOA is a hybrid algorithm developed by combining two metaheuristic algorithms, PSO and WOA. It integrates the complementary strengths of Particle Swarm Optimization (PSO) and the Whale Optimization Algorithm (WOA). The proposed algorithm works by combining PSO's social learning mechanism and WOA's spiral updating strategy. It achieves a well balanced exploration-exploitation trade off, and the structure not only improves a convergence speed but also enhance solution accuracy and robustness of the algorithm in complex resource allocation scenario.

**Results and Discussion:** Simulation results demonstrate that the proposed hybrid algorithm outperforms the standalone algorithms PSO and WOA. HPSOWOA achieves higher throughput and converge faster due to a balanced between local refinement and global exploration. It also attains a better fairness index compare to the standalone algorithms, indicating more balanced resource block distribution among the users. The overall analysis demonstrate that with superior throughput performance compare to existing standalone algorithms, the proposed hybrid algorithm improves spectrum reuse efficiency and interference aware allocation decision.

**Conclusion:** This work gives a nature inspired hybrid algorithm for improving resource block allocation in D2D communication. The proposed hybrid algorithm, namely HPSOWOA integrates the strengths of respective standalone algorithms to enhance the resource allocation by improving system throughput, fairness and packet loss. Results show that the hybrid algorithm outperforming both standalone algorithms, delivering the best overall performance through improved exploration-exploitation balanced and more efficient resource block allocation.

**Keywords:** D2D, Resource allocation, PSO, WOA, Hybrid PSO-WOA, Throughput, Fairness, Packet loss ratio

# PP-95: A Real-time Crop Recommendation System using Soil Sensor, Environment Parameter and AI/ML

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**Introduction:** The agricultural sector in India represents a significant contributor to the national economy, accounting for approximately 58% of the total workforce and 17% of the Gross Domestic Product (GDP). Crop yields are fundamentally influenced by a complex interplay of environmental and anthropogenic factors like soil composition, texture, and precipitation patterns. A primary challenge within Indian agriculture lies in optimizing crop selection to align with localized terrain and climatic conditions. NPK (Nitrogen, Phosphorus, Potassium) and pH are critical drivers of crop production; proper balance boosts yields by 10-20%, while imbalances or improper pH cause nutrient deficiencies, toxicity, and stunted growth. NPK provides essential nutrients for growth, and soil pH controls their availability. Along with soil fertility, the average rainfall, temperature and humidity also impact the crop productivity. For rice optimal value of Nitrogen is 120/ –/ 180 kg/ha, Phosphorous 60/ –/ 80 kg/ha, Potassium 120/ –/ 180 kg/ha, Soil pH 5.5/ –/ 6.5, average temperature 20/ –/ 32 °C, average rainfall 1500/ –/ 2000 mm/yr and atmospheric humidity 70/ –/ 80%. Similarly other crops have a range of values for each parameter. Using IoT based soil sensor to measure the NPK and pH of soil and combining with region specific environment data can predict the most suitable crop, hence improving the productivity and income for the farmer.

**Material and Methods**: The JXBS-3001-TR is used that works by utilizing advanced electro-chemical and dielectric principles to measure soil properties (moisture, EC, pH, NPK, temperature) and transmits this data via an RS485 Modbus-RTU interface. It is designed for long-term burial in soil, with a waterproof (IP68) construction and corrosive-resistant stainless-steel probes. The soil sensor is connected to ESP32 using a TTL-to-RS485 transceiver module (e.g., MAX485) to convert UART signals. The ESP32 reads the sensor data using MODBUS protocol and transmit the same to an android application using Bluetooth. The data with levelled recommended crop and suitable value of N, P, K, pH, Temperature, Humidity and Rainfall as features are collected. A Stacking Classifier ensemble model is trained to be used for recommendation using sci-kit python library. Random Forest, SVM Classifier and Multilayer Perceptron Classifier are used as estimators. The data is divided into 80:20 ratio for training and testing purpose. Once the model is trained, we export it as an ONNX model which can run in android environment to read the soil parameters from sensor, fetch the environmental parameter for the location using GPS and IMD data source. These information input to the pre-trained ONNX model to recommend the crop.

**Results and Discussion**: The training has shown result matrix of 99.32% accuracy, 0.9937 of Weighted Precision, 0.9931 of Weighted Recall and 0.9932 of Weighted F1-score. On a balance dataset the model matrix indicates a remarkably high level of performance. The values are extremely close to 1 (or 100%), suggesting the model is very accurate and reliable in its predictions. The balance between precision and recall is also excellent, highlighting that the model isn't sacrificing one for the other.

**Conclusion**: This work leverages on IoT-based sensor data and regional climate information with an aim to offer promising tools for predicting optimal crop choices and significantly boosting productivity, ultimately supporting farmer income and the nation's economic growth.

**Keywords**: ***Soil Sensor, Soil Fertility, Crop Recommendation, Precision Agriculture***

# PP-96: Adaptive Reinforcement Learning Optimized FOPID Control for Self-Balancing Robot

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**Introduction:** Self-balancing robots, modeled as inverted pendulum systems, require accurate real-time control to maintain stability. Although PID controllers are commonly used, fixed-gain tuning methods often struggle with nonlinear dynamics, uncertainties, and external disturbances. This paper presents an adaptive control strategy that integrates reinforcement learning with a fractional-order PID controller to improve robustness and flexibility. The Deep Deterministic Policy Gradient algorithm is employed to tune control parameters in continuous action spaces. Deep neural networks enable real-time regulation of tilt angle, angular velocity, and position. Simulation results show improved stabilization, reduced overshoot, and better disturbance rejection compared to conventional PID and block-based controllers. The inclusion of fractional-order terms enhances tuning flexibility and system robustness for complex robotic applications.

**Methods and Material:** The proposed framework uses a model-free RL approach with the DDPG algorithm in MATLAB/Simulink. Unlike Q-learning, DDPG handles continuous state and action spaces through an actor–critic structure. The actor generates control actions such as motor torque or adaptive PID/FOPID gains, while the critic evaluates them using Q-values. States include tilt angle, angular velocity, and position, and actions correspond to torque or gain parameters. Stability is ensured through experience replay and soft target updates. The FOPID controller extends classical PID with fractional integration (ë) and differentiation (ã) for improved control flexibility. Deep neural networks approximate policy and value functions, and key hyperparameters are tuned experimentally for stable convergence.

**Result and Discussion:** This research compares MATLAB PID Tuner, Block-Based Controller, RL Agent, and RL-FOPID. The MATLAB PID shows the fastest rise time with moderate overshoot, while the block controller exhibits excessive overshoot. The RL controller improves stability and reduces oscillations. The RL-FOPID delivers the best overall performance, limiting overshoot to ~10% with strong disturbance rejection. Optimal stability is achieved at ã = 0.6 and ë = 0.5.

**Conclusion:** The integration of RL with FOPID significantly enhances adaptability and robustness compared to fixed-gain PID control. The DDPG-based adaptive approach provides improved balancing performance under nonlinear conditions, with potential for future hardware implementation and advanced RL extensions.

**Keywords:** Reinforcement Learning, FOPID, DDPG, Self-Balancing Robot, Adaptive Control.

# PP-97: Design and Performance Analysis of a Digital Logic Implementation

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**Introduction:** This paper presents the design, implementation, and performance evaluation of a digital logic slice implemented using three different logic design approaches: basic logic gates, a universal gate-only configuration, and a hierarchical design. The basic gate implementation serves a baseline architecture, while the NAND-only implementation exploits the functional completeness and regularity, which is beneficial for gate-level optimization and uniform fabrication processes. The hierarchical design approach emphasizes on modular and hierarchical digital design principles. All architectures are described using VHDL due to its strong support for modular and hierarchical design and synthesized using an FPGA-based design flow. The implementations are evaluated quantitatively in terms of input/output blocks (IOBs), look-up tables (LUTs), and propagation delay. The study provides insight into how logic structure and design style influence scalability and efficiency.

**Methods and Materials:** In this approach, an adder slice is implemented using extended and basic and gates like XOR, AND, and OR. This approach offers a simple and efficient design with minimal logic depth. The NAND-only realizes all required logic functions but this increases the number of logic levels, it is useful for demonstrating uniform gate design and understanding gate-level synthesis. In the hierarchical approach, two half adders are cascaded, and their carry outputs are combined using an OR gate to form an adder slice. This design emphasizes modularity, reusability, and hierarchical construction, which are desirable traits in large digital systems.

**Results and Discussion:** The number of IOB used for implementation in each design style is similar as the number of inputs and outputs remains unchanged. However, differences in LUT utilization and propagation delay arise due to variations in logic depth and gate composition. The maximum numbers of LUT were used for the implementation of the NAND based design. This design technique also exhibited maximum propagation delay of 3.4 ns. While the basic gate level used lesser LUTs than the hierarchical design. The propagation delay exhibited by the basic gate implementation is 2.1 ns while that offered by the hierarchical design is 2.7 ns. Thus, the basic logic gate implementation is observed to be the most efficient design. The NAND-only implementation exhibits increased LUT usage and higher delay due to deeper logic levels. The half-adder-based design provides a balanced trade-off between modularity and performance.

**Conclusion:** This paper presented the design, VHDL implementation, and comparative analysis of an adder slice using three different logic design approaches. The results highlight trade-offs among hardware utilization, delay, and design complexity, making this work suitable for digital design and FPGA-based arithmetic circuit analysis. These differences become more significant when extended to n-bit adder architectures, particularly in ripple-carry configurations where carry propagation delay dominates overall performance.

**Keyword:** *Adder, VHDL, FPGA Implementation, NAND Gate, Look-Up Table (LUT), Input/Output Block (IOB), Propagation Delay.*

# PP-98: CNT and ZnO Nanomaterials-Based Fractional Capacitive Sensors for Real-Time Water Impurity Identification

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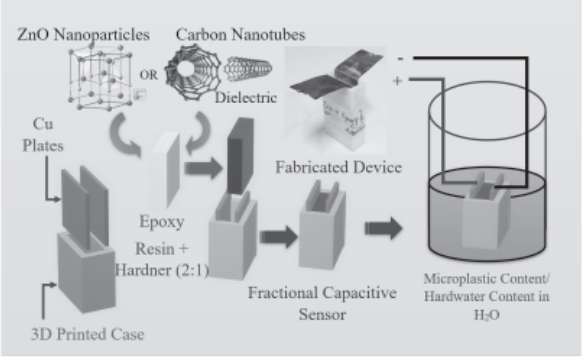
**Introduction:** Fractional capacitive sensors, based on fractional-order circuit elements, offer a powerful alternative by inherently incorporating non-ideal and memory-dependent dielectric behavior into the sensing element itself. A fractional capacitor, commonly modeled as a constant phase element, exhibits an impedance that follows a power-law frequency dependence, which can model complex biochemical and electrochemical behavior. Therefore, a fractional capacitor with nanocomposite materials is a powerful tool for detecting water impurities, using specific nanomaterials (e.g., ZnO and CNT) to sense particular impurities (e.g., hardness or microplastic content) in water.




**Methods and Materials:** ZnO nanoparticles and Carbon nanotubes at different concentrations in epoxy gel have been used as a dielectric between two copper plates. This fabricated structure has the properties of a fractional capacitor, i.e., $C_á$ and á, which are dependent on the microplastic as well as hardwater content in a sample of water. Different concentrations of hardwater and microplastic content in water have been taken to obtain the dependency of the fractional-capacitor properties on the measurand.

**Result and Discussion**: The fabricated sensor provides different magnitude (roll off rate) as well as phase shifts with a change in microplastic and hardwater content in water. This change is in non-integer order, relating the fractional order (á) and fractional-capacitance ($C_á$) to the impurity content.

**Conclusion:** This research mathematically models, simulates, fabricates, and experimentally designs a fractional-capacitive sensor for the determination of microplastic and hardwater content in water.

**Keywords:** ***Fractional-capacitor, sensor fabrication, Nanotechnology, ZnO nanomaterials, Carbon nanotubes***

# PP-99: CuO Nanomaterials-based Ultra-Low Order (á H”0.01) Fractional-Capacitor for Stability Improvement in Nuclear Reactors

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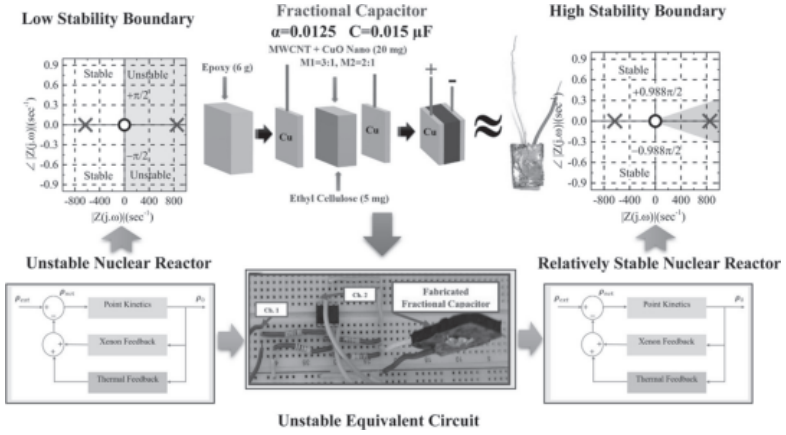
**Introduction:** The Advanced control strategies are required for nuclear reactor systems due to their strongly nonlinear, multi-time-scale dynamics arising from neutron kinetics, thermal feedback, and xenon poisoning. Conventional integer-order capacitors, characterized by a fixed “90° phase response, impose strict left-half-plane stability constraints. This research introduces a novel approach by employing a CuO nanomaterial-based ultra-low-order fractional capacitor to overcome these limitations. With a fractional order of approximately á H” 0.01, the proposed device provides a near-99% stability probability, significantly expanding the stability boundary.




**Methods and Materials:** The fractional capacitors M1 and M2 were fabricated using an epoxy-based nanocomposite containing MWCNTs, CuO nanoparticles, and ethyl cellulose. Both samples used a 2:1 epoxy resin–hardener system with fixed matrix mass, while M2 employed higher filler loading than M1. The materials were mixed, ultrasonicated, degassed, cast, and cured under controlled conditions. The cured composites were sandwiched between copper electrodes in a parallel-plate configuration for device realization.

**Result and Discussion**: The fabricated devices achieved ultra-low fractional orders of á = 0.0115 (M1) and á = 0.0125 (M2), exhibiting an approximately constant phase over bandwidths of 1–200 kHz and 1–100 kHz, respectively. The extracted fractional capacitor, when integrated into an unstable nonlinear nuclear reactor model, without pole relocation, achieves an estimated stability probability of ~99% with negligible long-term drift over eight months.

**Conclusion:** Unlike conventional compensator-based approaches, the (á = 0.0115) intrinsically enhances stability (~99%) by expanding fractional stability boundaries through a small but physically grounded constant phase. Its successful application in a nuclear reactor dynamic model highlights its potential as a passive, reliable, and radiation-tolerant stabilising element for advanced nuclear control architectures.

**Keywords:** ***Fractional capacitor CuO nanoparticles, MWCNT, Nuclear reactor, Stability improvement, Low order***

# PP-100: SAR analysis of antenna with AMC for 5.8 GHz ISM band for WBAN applications

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**Introduction:** The 5.8 GHz ISM band is widely used for high data rate Wireless Body Area Network and wearable Communication Systems. However, when the traditional microstrip antennas are kept near to human body, the electromagnetic absorption and detuning affects the antenna performance while increasing the specific absorption rate (SAR) value. Artificial magnetic conductor or metasurface structure are used to enhance the antenna performance when placed near human body by reducing the back radiation which in turns decrease the SAR values. This work represents the antenna integrated with AMC to operate at 5.8 GHz to enhance the antenna performance while minimizing the SAR value.

**Materials and Methods:** A compact antenna with Rogers RO4003C substrate ($\varepsilon_r = 3.6$) is designed to operate at 5.8 GHz. A 2×2 AMC is designed with felt substrate ($\varepsilon_r = 1.36$) using transmission line model and placed beneath the antenna. The antenna integrated with AMC is simulated on both free space as well as on human body to check how the antenna performance behaves. Full wave simulations are performed to analyse the S11, gain, and SAR parameters by keeping the whole antenna near a human body model as well as in free space.

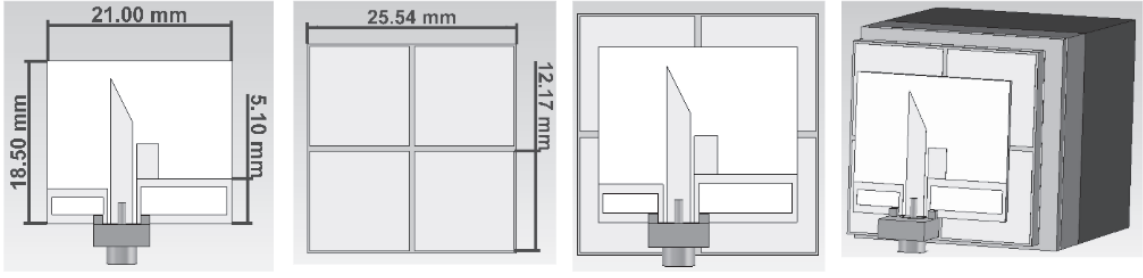


Fig 1: (a) Patch Antenna (b) 2×2 AMC (c) antenna Integrated with AMC (d) Antenna with AMC on Human body

**Results and Discussions:** In free space, the antenna with AMC is found to be resonate at 5.8 GHz with a S11 value of -50 dB with an impedance bandwidth of 1730 MHz and a gain of 7.05 dBi. When the same antenna with AMC is placed near human body, it resonates at 5.70 GHz with a S11 value of -22 dB at 5.8 GHz. The antenna with AMC exhibits a impedance bandwidth of 1700 MHz and a gain of 6.5 dBi near human body. That shows a good isolation between human body and antenna. The shift in the resonating frequency is due to the affect of human body properties on the antenna. When only microstrip antenna is placed near human body, it shows a SAR value of 16.5 W/Kg average over 10 g of tissue where as the antenna with AMC shows a SAR value of 1.49 W/Kg over 10 g of tissue which is well below the safely limits of 1.6 W/Kg over 10 g of tissue.

**Conclusions:** The proposed AMC based antenna resonates at 5.8 GHz. The antenna with AMC maintains stable antenna performance when simulated in free space and on human body. The antenna with AMC gives a SAR value of 1.49 W/Kg over 10 g of tissue and a gain of 7.05 dBi, making it a suitable candidate for WBAN applications.

**Keywords:** Microstrip antenna, SAR, Artificial magnetic conductor, WBAN

# PP-101: Design and TCAD Simulation of Gate-All-Around TFET

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**Introduction:** As CMOS technology approaches its scaling limits, conventional MOSFETs suffer from increased leakage current, degraded subthreshold swing, and severe short-channel effects. Tunnel Field-Effect Transistors (TFETs), operating on the principle of band-to-band tunneling (BTBT), have emerged as promising alternatives for ultra-low-power applications. Among various architectures, the Gate-All-Around (GAA) structure provides superior electrostatic control over the channel, thereby enhancing switching characteristics and suppressing leakage. This work presents the design and TCAD simulation of a 20 nm channel length GAA-TFET aimed at achieving high ON-current with extremely low OFF-state leakage.

**Methods and Material:** The proposed cylindrical GAA-TFET structure was designed and simulated using Silvaco ATLAS TCAD tools. A silicon wire channel fully surrounded by a high-k gate dielectric and metal gate was considered to ensure strong gate control. The source region was heavily p-doped and the drain region n-doped to enhance band-to-band tunneling at the source-channel junction. Advanced physical models including Non-local BTBT, Shockley–Read–Hall recombination, Fermi–Dirac statistics, and concentration-dependent mobility were incorporated for accurate device behavior prediction. Electrical characteristics such as transfer characteristics ($I_d$–$V_g$), ON-current ($I_{ON}$), OFF-current ($I_{OFF}$), and current ratio were extracted at a channel length of 20 nm.

**Result and Discussion:** Simulation results demonstrate excellent switching performance of the proposed GAA-TFET. At a channel length of 20 nm, the device achieved an ON-current ($I_{ON}$) of 1.86 × 10{ t A/μm and an extremely low OFF-current ($I_{OFF}$) of 5.76 × 10{ ¹x A/μm, resulting in an outstanding $I_{ON}/I_{OFF}$ ratio of approximately $3.23 \times 10^{13}$. The ultra-low OFF-state leakage confirms strong electrostatic integrity and effective suppression of short-channel effects due to the GAA architecture. The high ON-current indicates efficient band-to-band tunneling at the source-channel interface. The results validate that the surrounding gate configuration significantly enhances carrier control compared to planar TFET structures, making the device highly suitable for nanoscale low-power logic applications.

**Conclusion:** The 20 nm Gate-All-Around TFET designed and simulated using TCAD demonstrates exceptional switching performance with high ON-current and ultra-low OFF-current. The obtained $I_{ON}/I_{OFF}$ ratio of the order of $10^{13}$ highlights the strong potential of the GAA-TFET architecture for next-generation ultra-low-power integrated circuits. The study confirms that structural optimization combined with advanced tunneling models can significantly improve device efficiency for future semiconductor technologies.

**Keyword:** ***GAA-TFET, TCAD Simulation, Band-to-Band Tunneling, Low-Power Devices, 20 nm Technology***

# PP-102: Design of Approximate Multipliers for Error Tolerant Applications

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**Introduction:**Multipliers are essential components in digital signal processing, image processing, and embedded systems, where speed and power efficiency are critical design parameters. Various multiplication techniques which find immense benefits in real time applications have been worked on and continue further to design power and area efficient multipliers with increased performance as well. On comparing multipliers designed using exact and inexact adders along with parallel adders leads to the design of approximate multipliers, that focuses on the idea of trading precision to design power and area efficient circuits. Applications like error tolerance use approximation to trade-off accuracy and obtain low area/power/delay circuits. This work focuses on designing 4-bit and 8-bit approximate multipliers using inexact adders and Error Prediction and Correction Logic (EPCL) along with parallel adders such as Ripple Carry Adder (RCA),Carry Save Adder (CSA), Carry Skip Adder (CSKA) and Carry Look-Ahead Adder (CLA) which are beneficial in Error tolerant applications as inferred from the Relative Error Distance (RED)/Mean Relative Error Distance (MRED) calculations. However, conventional exact designs often result in higher power consumption and delay. This work also presents the design of a 8-bit approximate multiplier using ACMLC and CAC and approximate Dadda multiplier to enhance performance by reduced power consumption.

**Methods and Material:**In the proposed modified multiplier, partial products are generated using conventional AND and OR gates and arranged according to the circuit requirements. The reduction stages incorporate ACMLC and CAC, 4:2 compressors and other minor circuits to decrease the number of reduction levels and shorten the critical path. The final addition stage is implemented using parallel adders. The design is modelled and simulated using Verilog HDL to evaluate power, LUTs and error.

**Results and Discussion:**Simulation results demonstrate improved reduced power consumption compared to the conventional exact Wallace tree multiplier. Although minor computational errors are introduced due to approximation, the accuracy remains acceptable for error-resilient applications such as multimedia and signal processing systems.

**Conclusion:** The proposed 4 and 8-bit approximate multiplier achieves reduced power and area (LUTs) consumption while maintaining acceptable accuracy. The architecture is suitable for high-performance, energy-efficient VLSI applications where limited computational error is tolerable.

**Keywords:***Approximation, Accuracy, Inexact adders, Partial product, EPCL, Power, LUTs,Majority Logic, Compressors, Dadda Multiplier, Error-Tolerant*

# PP-103: AI-Based Accuracy Enhancement Framework for Low-Cost Sensor Systems Using Adaptive Sensor Fusion and Edge Modeling

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**Introduction**: A critical barrier to the scalability of Smart City infrastructure is the "Hardware Cost-Accuracy Gap." Industrial-grade monitoring stations *(H"¹ 1,30,000*) offer *±1% accuracy* but are financially inaccessible for widespread public deployment. Conversely, low-cost sensors *(H"¹ 85–¹ 700*) suffer from high stochastic noise, cross-sensitivity, and temporal drift. This research proposes an AI-based framework that utilizes Redundant Sensor Arrays and Edge Modeling to achieve near-industrial measurement reliability. By shifting the burden of accuracy from expensive physical materials to computational intelligence, we enable a 90% cost reduction in public safety instrumentation. By decentralizing high-precision monitoring, this framework transitions public safety from a reactive luxury to a proactive, data-driven right for all socio-economic strata. Ultimately, this research provides a scalable blueprint for Resource-Constrained Cyber-Physical Systems (RC-CPS) that can be deployed across poorly infrastructure urban environments without compromising on decision-critical accuracy.

**Methods and Materials:** The proposed architecture is structured into a cohesive three-stage processing pipeline executed entirely on the ESP32 microcontroller to ensure low-latency and autonomous operation. At the foundational level, the system utilizes a Redundant Sensor Array to mitigate the stochastic noise inherent in low-cost hardware. Rather than relying on a single data point, a cluster of *n* sensors is aggregated through a weighted average, defined by $X_{fused} = \sum_{i=1}^{n} w_i x_i$, where $w_i$ represents the dynamic confidence weight of each unit. This fused signal is then passed to a Drift Detection & Kalman Filtering layer, which employs a recursive predictive-update cycle to track the *true state* of the environmental variables, effectively stripping away long-term temporal sensor drift. The final layer of the framework utilizes TinyML Error Compensation, where a Gradient Boosting Regressor ($R^2 = 0.970$) maps the refined fused output to an industrial-grade reference value. To maintain the system's resource constrained footprint, the model is compressed via 8-bit quantization, allowing it to operate comfortably within the 520KB SRAM of the ESP32. This approach eliminates the overhead of cloud dependency, ensuring sub-millisecond response times critical for real-time public safety applications.

**Results and Discussion:** Comparative analysis between a high-quality industrial sensor of accuracy ±1% and the proposed AI-enhanced system costing about *BOM H"¹ 2,500* demonstrates that the framework improves raw sensor error from *±12% down to ±2.5%.* This validates that the system reaches *93% of industrial-grade accuracy at 1/50th of the cost.* A key challenge addressed here is the Sensor Aging i.e. the AI module identifies slow deviations (drift) beyond statistical norms and flags specific sensor modules for low-cost replacement *(<¹ 100*). The Life Cycle Cost analysis proves that a modular replacement strategy is *5x* more economically efficient than repairing a single high-end unit.

**Conclusion:** This research bridges the critical economic divide in environmental monitoring by transitioning high-precision sensing from an elite privilege to a public utility. By integrating redundancy, Kalman filtering, and Edge AI, we can provide a scalable, high-accuracy solution that is accessible to middle-income and marginalized communities alike. This framework's *90% reduction* in upfront hardware costs, coupled with a modular maintenance strategy, allows government agencies to deploy massive sensor networks with minimal long-term fiscal burden & provide localized, real-time alerts in high-risk zones where high-cost stations are unfeasible. Ultimately, this work equalizes real-time safety data, proving that resource-constrained environments can achieve industrial-grade protection through the power of intelligent & frugal engineering.

**Keywords:** Resource Constrained/ Frugal Engineering, Redundant Sensor Arrays, Edge Modeling, Sensor Fusion, TinyML, Drift Modeling, Edge AI, Instrumentation, BOM-Bill Of Materials.

# PP-104: Design and analysis of L-shaped slot CPW-fed Microstrip antenna for Multi-band applications

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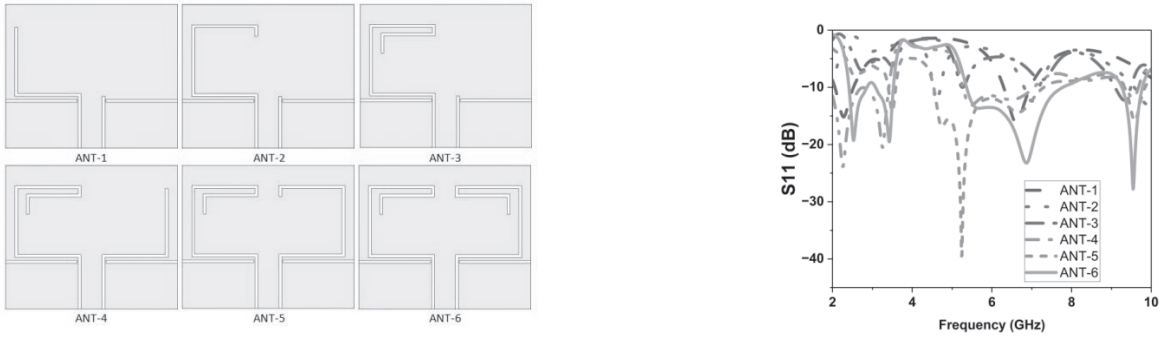
**Introduction:** The rapid growth of current wirelesss communication system has contributed to the demand for compact, low profile, multi band antennas that can support various applications such as wireless, radar and satellite communication system. Microstrip antennas are favour for these multi band applications due to their light weight, low fabrication cost and easy of integration with other planar devices. The coplanar waveguide feeding (CPW) technique is used due to its high impedance bandwidth, lower radiation loss and easy integration with active components. However, achieving multiband properties with compact structure while maintaining steady radiation pattern over wide frequency band remains major design challenge. This work proposes an antenna to operate at 2.451 GHz (S-band), 3.528 GHz (S-band), 6.875 GHz (C-band) and 9.548 GHz (X-band) frequencies, prevalent in wireless communication, radar, satellite, and weather monitoring systems.

**Methods and Material:** The proposed antenna features a CPW-fed microstrip antenna, embedded with dual folded L and inverted L-shaped slots on copper (annealed) patch on FR-4 (lossy) substrate. It is designed in six stages. In the initial stages, dual-bands are observed at 2.284 GHz and 6.618 GHz. To enable the multi-band performance, adding and etching of L-slot operations are done which shows the results at 2.451 GHz, 3.528 GHz, 6.875 GHz and 9.548 GHz to make it useful for wireless, Radar and satellite communication systems.




(a) (b)

Fig-1: (a) Evolution of antenna, (b) Return loss of antennas at multi-band frequency

**Results and Discussions:** The proposed antenna shows four frequency bands : Band 1 (2.411-2.863 GHz), Band 2 (3.072-3.528 GHz), Band 3 (5.352- 7.794 GHz) and Band 4 (9.251-9.773 GHz) having return losses of -19.23 dB, -19.43 dB, -23.22 dB, and -27.69 dB respectively and gain of 0.21 dB at 2.45 GHz, 0.51 dB at 3.418 GHz, 3.77 dB at 5.85 GHz, 2.20 dB at 6.875 GHz, and 0.66 dB at 9.548 GHz respectively.

**Conclusions:** The proposed CPW-fed microstrip antenna with dual folded L and inverted L-shaped slots achieves compact and efficient multi-band characteristics with improved gain. Slot adjustment improves the existing distribution yielding resonances at 2.45 GHz, 3.5 GHz, 6.875 GHz and 9.548 GHz, applicable for wireless, satellite and weather monitoring systems.

**Keywords:** Microstrip antenna, Multi-band, CPW feeding, Satellite communication

# PP-105: Algorithmic Evaluation of Soil Nutrient and Moisture Data for Precision Agriculture Using Machine Learning Techniques

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**Introduction**: Efficient soil health assessment is essential for data-driven precision agriculture. Traditional soil analysis relies on laboratory testing and manual interpretation, which are time-consuming and often inaccessible for small-scale decision-making. With the availability of structured soil datasets containing nutrient and moisture parameters, computational modelling provides an opportunity to automate soil classification for crop suitability prediction. This study presents a simulation-based analytical framework that evaluates soil nutrient like Nitrogen (N), Phosphorus (P), Potassium (K), and moisture parameters using machine learning algorithms to support agricultural decision-making under controlled computational conditions.

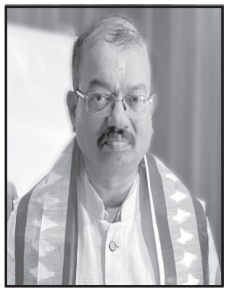
**Methods and Material**: A structured soil dataset comprising N, P, K, and soil moisture features was utilized for computational analysis. Data preprocessing involved normalization and feature scaling to ensure statistical consistency and to mitigate magnitude-related bias across variables. Random Forest (RF) was selected as the baseline model due to its ensemble learning architecture, robustness against overfitting, capability to capture nonlinear interactions, and effectiveness in handling correlated predictors. To enhance model robustness, hyperparameter tuning was conducted using Grid Search Cross-Validation, optimizing parameters such as the number of trees (n_estimators), maximum tree depth, and minimum samples required for node splitting. Apart from that, K-fold cross-validation was further implemented to ensure generalization and to minimize the variance bias. Model performance was evaluated using Accuracy, F1-score, $R^2$, and Area Under the Receiver Operating Characteristic Curve (AUROC), by using different optimizers like RF-PSO, RF-WOA and RF-Walrus enabling comprehensive assessment of classification performance, predictive strength, and discrimination capability for choosing the correct crop suitability.

**Result and Discussion:** The optimized RF-Walrus model demonstrated an improved predictive stability with an accuracy of 96.28, compared to other models as mentioned by using the hyperparameter tuning enhanced models' generalization across validation folds. Performance evaluation indicated strong classification consistency as reflected by Accuracy and F1-score, while $R^2$ values confirmed reliable explanatory capability. The AUROC metric demonstrated effective discrimination between different crop classes like wheat, rice etc, indicating robustness in decision boundary formation.

**Conclusion**: This study establishes an optimized Random Forest-based computational framework for soil nutrient and moisture evaluation under simulated conditions with different optimizers. The findings demonstrate that ensemble learning combined with systematic hyperparameter optimization yields reliable predictive performance. Although limited to computational validation, the framework provides a statistically grounded basis for future integration with real-time soil sensing systems and field-level experimentation.

**Keywords:** · Crop recommendation · Machine learning · Metaheuristic optimization · Random Forest · Particle Swarm Optimization Algorithm · Whale Optimization Algorithm · Walrus Optimization Algorithm ·

# PP-106: Strategy for Total Development of Local Areas (TODOLA) with 5G+ Standard Operating System for Indian Languages (SOIL)



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## Introduction

The paradigm of rural development is undergoing a fundamental shift, moving from simple infrastructure provision to complex, technology-enabled ecosystem transformation. As nations deploy high-speed data communication networks—including 5G and the nascent 6G—to remote hinterlands, the challenge evolves from "connecting the unconnected" to ensuring "meaningful connectivity" that drives Total Development of Local Areas (TODOLA). People in India speak, understand and communicate in Indian Languages. After many years National Education policy highlights the importance of Indian language. Standard Operating System in Indian languages is to establish technology base in Indian languages starting from Assembly language level.

## Materials and Methods:

TODOLA model advocates for a "Whole-of-Local Area" economic model. The research synthesizes international best practices, including the International Telecommunication Union's (ITU) Smart Village Blueprint in Niger, South Korea's Information Network Village (INVIL) program, and the European Union's Smart Rural 21 initiative, to offer a comparative roadmap. This study also encompasses the Smart Intelligent village concept of Department of Telecom. Total development of ICT equipments like mobile or switches from Raw materials to finished product in India has also been studied. International scenario on 5G implementation and International researches in the direction of Native AI, Semantic Network in the direction of 6G are also studied. The Sanskrit language specifically Astadhyayi of Panini has been studied in the SOIL part in this direction

## Results and Discussions

The 1G to 5G were basically either connecting people or connecting machines. The vision for 6G is connecting intelligence. 6G will have Native Intelligence as the base. We may not need more –G if we achieve the goal of Total Development with AI. So the vision of TODOLA has been analyzed in detail with reference to first India and then world with some case studies. Similarly, in Native AI front use of structured language Sanskrit and its use in realizing the vision of connecting Intelligence using SOIL has been established. However, the study is going on and soon we may see the path breaking technology through this research.

## Conclusion

This report provides an exhaustive analysis of the TODOLA framework and its technological part, the Standard Operating System for Indian Languages (SOIL) with the objective of "connecting intelligence" vision of 6G, as conceptualized for the Indian context. The report concludes with a detailed strategic pathway for policy formulation, standardization, pilot implementation and scaling across India to realize the vision.

**Key words:** 5G, 6G, Connecting Intelligence, Native AI, TODOLA, SOIL

# PP-107: AMC based Wearable antenna for 2.45 GHz ISM band for WBAN application

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**Introduction:** Wearable antennas operating in the ISM 2.45 GHz are extensively used in Wireless Body Area Network (WBAN) and offbody communications. However, when the traditional microstrip antennas are kept near to human body, the electromagnetic absorption and detuning affects the antenna performance while increasing the specific absorption rate (SAR) value. Artificial magnetic conductor or metasurface structure are used to enhance the antenna performance when placed near human body by reducing the back radiation which in turns decrease the SAR values. This work represents the antenna integrated with AMC to operate at 2.45 GHz to enhance the antenna performance while minimizing the SAR value.

**Materials and Methods:** A compact antenna with felt substrate is designed to operate at 2.45 GHz. A 2×2 AMC is designed using transmission line model and placed beneath the antenna. The antenna integrated with AMC is simulated on both free space as well as on human body to check how the antenna performance behaves. Full wave simulations are performed to analyse the S11, gain, and SAR parameters by keeping the whole antenna near a human body model as well as in free space.

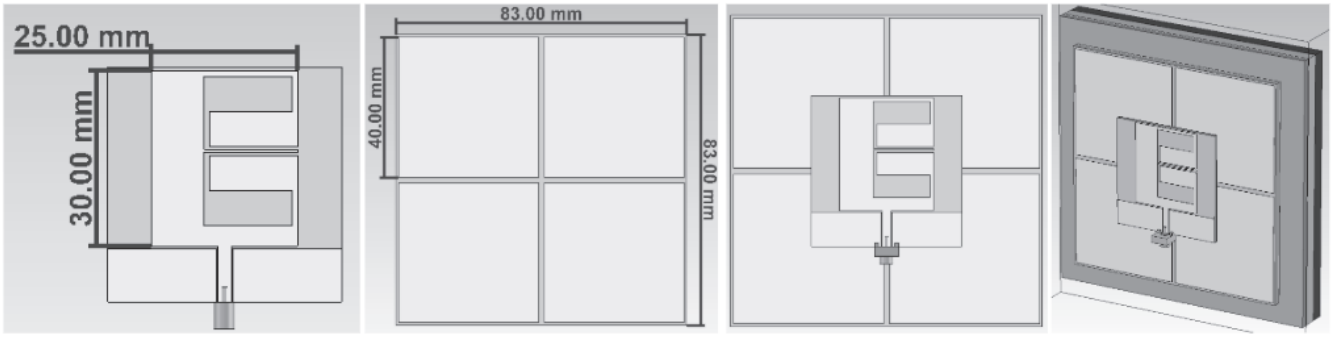


Fig 1: (a) Patch Antenna (b) 2×2 AMC (c) antenna Integrated with AMC (d) Antenna with AMC on Human body

**Results and Discussions:** In free space, the antenna with AMC is found to be resonate at 2.47 GHz with a S11 value of -41 dBi with an impedance bandwidth of 270 MHz and a gain of 7.41 dBi. When the same antenna with AMC is placed near human body, it resonates at 2.45 GHz with a S11 value of -42 dB. The antenna with AMC exhibits a impedance bandwidth of 260 MHz and a gain of 7.18 dBi near human body. That shows a good isolation between human body and antenna. When only microstrip antenna is placed near human body, it shows a SAR value of 13.8 W/Kg average over 10 g of tissue where as the antenna with AMC shows a SAR value of 0.508 W/Kg over 10 g of tissue which is well below the safely limits of 1.6 W/Kg over 10 g of tissue.

**Conclusions:** The proposed AMC based antenna resonates at 2.45 GHz. The antenna with AMC maintains stable antenna performance when simulated in free space and on human body. The antenna with AMC gives a SAR value of 0.508 W/Kg over 10 g of tissue and a gain of 7.18 dBi, making it a suitable candidate for WBAN applications.

**Keywords:** Microstrip antenna, SAR, Artificial magnetic conductor, WBAN

# PP-108: Design of 8-Bit Modified Dadda Multiplier Using Approximate Computing

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**Introduction:** Multipliers are essential components in digital signal processing, image processing, and embedded systems, where speed and power efficiency are critical design parameters. The Dadda multiplier is widely adopted due to its optimized partial product reduction technique. However, conventional exact designs often result in higher power consumption and delay. Approximate computing has emerged as an effective approach to improve energy efficiency by allowing controlled inaccuracies in error-tolerant applications. This work presents the design of an 8-bit modified Dadda multiplier using approximate computing to enhance performance and reduce computational time.

**Methods and Material:** In the proposed modified multiplier, partial products are generated using conventional AND gates and arranged according to the Dadda reduction scheme. The reduction stage incorporates 4:2 compressors to decrease the number of reduction levels and shorten the critical path. To further optimize performance, adders and approximate 4:2 compressors are selectively employed in non-critical paths, reducing computational time. The final addition stage is implemented using a carry-propagate adder or ripple carry adder. The design is modelled and simulated using Verilog HDL to evaluate delay, LUTs and error.

**Results and Discussion:** Simulation results demonstrate improved speed and reduced power consumption compared to the conventional exact Dadda multiplier. Although minor computational errors are introduced due to approximation, the accuracy remains acceptable for error-resilient applications such as multimedia and signal processing systems. The integration of approximate units with 4:2 compressors provide an effective trade-off between accuracy and hardware efficiency.

**Conclusion:** The proposed 8-bit modified Dadda multiplier using approximate computing achieves enhanced speed while maintaining acceptable accuracy. The architecture is suitable for high-performance, energy-efficient VLSI applications where limited computational error is tolerable.

**Keywords:** *Dadda Multiplier, Approximate Computing, 4:2 Compressor, Partial Product Reduction, Error-Tolerant Systems, Verilog HDL*

# PP-109: Reversible Data Hiding in Encrypted Images using RRBE and MED-based Prediction with Lightweight Auxiliary Data Control

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**Introduction:** With the increasing use of cloud storage and remote image processing, ensuring both confidentiality and exact image recovery is essential in applications such as medical imaging and secure surveillance. Reversible data hiding in encrypted images (RDHEI) provides dual functionality: secure payload embedding and perfect image reconstruction. Although reserving-room-before encryption (RRBE)-based approaches provide higher embedding capacity than vacating room after encryption (VRAE) schemes, they often suffer from high auxiliary-data overhead and synchronization complexity. This work proposes a lightweight RRBE-based RDHEI framework integrating median edge detector (MED) prediction, compact 2×2 block labeling, Huffman-compressed auxiliary data, and controlled bit-plane rearrangement to achieve high embedding efficiency with strict reversibility.

**Materials and Methods**: The proposed framework consists of four phases: (1) MED-based prediction to compute absolute prediction errors, (2) 2×2 block partitioning to generate an 8-level Block Label Map (BLM), (3) Huffman compression of BLM combined with LSB backup and header information to reduce auxiliary overhead, and (4) controlled bit-plane rearrangement to reserve contiguous embedding space before encryption. The preprocessed image is encrypted using a stream cipher (XOR/AES-CTR), and secret data are embedded in reserved encrypted LSB positions.

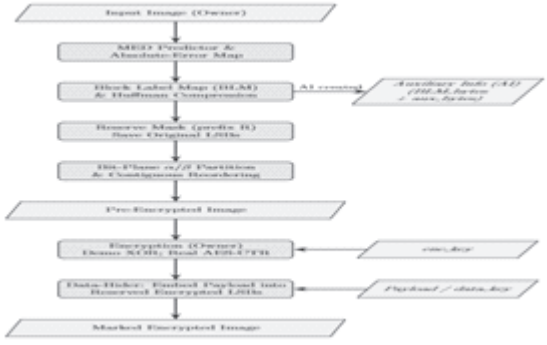

Figure 1: Proposed RRBE-based encryption and data embedding workflow

**Results and Discussion:** The proposed method was evaluated on standard grayscale images such as Cameraman, Peppers, Rice, Coins, and Moon. The scheme achieved embedding rates up to 0.51 bpp with significantly reduced auxiliary data compared to multi-MSB RRBE methods. After decryption, PSNR values remain low (8–13 dB) due to encrypted-domain embedding; however, after complete inverse processing, four images achieved exact recovery (MSE = 0), corresponding to infinite PSNR. The Moon image achieved approximately 65 dB, which is visually lossless. Rate–distortion analysis confirms exact reconstruction across a wide embedding range until the reservable capacity is exhausted.

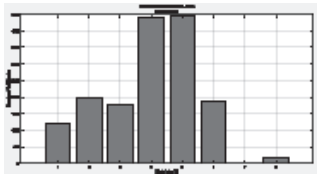

Figure 2: 2×2 block label distribution (Cameraman) highlighting smooth-block dominance.

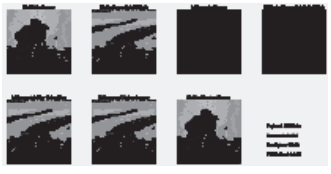

Figure:3: Visual workflow from original to fully restored image.

**Conclusion:** The proposed RRBE-based RDHEI framework achieves a balanced trade-off among embedding capacity, auxiliary-data reduction, and strict reversibility. By integrating MED prediction, compact 2×2 labeling, and Huffman-compressed metadata, the scheme reduces synchronization complexity while maintaining high embedding flexibility. Experimental results confirm exact or near-exact recovery with lower overhead than existing multi-MSB methods. The approach is well-suited for privacy-sensitive cloud and medical applications.

**Keywords**: Reversible Data Hiding, RDHEI, RRBE, MED Prediction, Huffman Coding, Bit-plane Rearrangement, Auxiliary Data Reduction.

# OP-110: Groundwater vulnerability assessment using DRASTIC model and GIS: A case study of Sundargarh District, Odisha, India

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**Introduction:** Groundwater is the most important source of water supply due to its availability and low vulnerability to pollution compared to surface water. This study was carried out to determine the groundwater vulnerability and susceptible zones in Sundargarh District, Odisha by integrating hydrological layers of DRASTIC model using GIS. It is necessary for sustainable water resource management and support effective groundwater protection planning

**Materials and Methods**: The current study uses the GIS-based DRASTIC model to assess groundwater vulnerability in the Sundargarh district of Odisha. By combining seven hydrogeological parameters—depth to water table, net recharge, aquifer media, soil media, topography, impact of the vadose zone, and hydraulic conductivity—DRASTIC, an index-based method, evaluates intrinsic groundwater vulnerability. The Central Ground Water Board (CGWB), the Geological Survey of India (GSI), the National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), satellite imagery, and digital elevation models were among the secondary sources from which spatial datasets for these parameters were gathered. ArcGIS software was used to prepare and analyze each thematic layer in a GIS environment. In accordance with standard DRASTIC guidelines, each parameter was categorized into appropriate ranges and given ratings and weights that reflected their relative impact on groundwater contamination. Weighted overlay analysis was used to determine the DRASTIC vulnerability index.

**Results and Discussion:** Weighted Sum tool in ArcGIS was used to integrate the reclassified raster layers of the seven DRASTIC parameters, and the process produced a final DRASTIC vulnerability index value of 165, indicating the composite intrinsic vulnerability of the study area. According to Aller et al. (1987), the resulting vulnerability map falls under the moderate contamination risk category. The map uses three colour codes: green for low vulnerability, yellow for moderate vulnerability, and red for high vulnerability zones. Low-vulnerability areas are generally associated with deeper water tables and low permeability, while high-vulnerability zones correspond to shallow water tables, high recharge, and permeable aquifer and soil conditions. To evaluate the reliability of the DRASTIC model, validation was carried out using nitrate concentration data from CGWB (2023). Nitrate was selected due to its strong association with anthropogenic activities. A Receiver Operating Characteristic (ROC) curve analysis was performed using a threshold of 45 mg/L. The obtained AUC value of about 0.80 confirms good predictive performance, demonstrating the model's practical applicability for groundwater management in Sundargarh district.

**Conclusion/Recommendation:** The DRASTIC model revealed that groundwater vulnerability in Sundargarh varies due to interacting hydrogeological factors, with blocks like Kutra, Balisankara, and Bonai showing high risk. The study highlights DRASTIC as an effective tool for identifying priority zones and supports targeted groundwater protection, monitoring, and sustainable management through improved planning and community awareness.

**Keywords**: GIS, Sundargarh, groundwater, DRASTIC, Vulnerability index

# OP-111: Achieving Low Cost Net-Zero Residential & Office Buildings in Various Climatic Conditions of India

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**Introduction:** Buildings contribute significantly to total energy consumption due to heating, cooling, ventilation, and lighting demands. Rapid urbanization, rising energy costs, and increasing temperature extremes have made energy-efficient building design both an environmental necessity and an economic priority. This research focuses on achieving low-cost net-zero energy performance in residential and office buildings across different climatic regions of India using climate-responsive and economically viable design strategies.

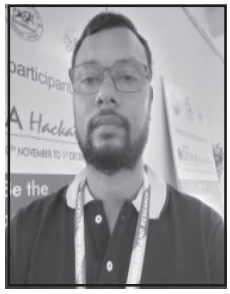
**Materials and Methods:** The study evaluates active, passive and hybrid building strategies including optimal orientation, controlled window-to-wall ratio, natural ventilation, reflective and green roofs, and phase change material-based thermal storage. Architectural interventions such as shading devices, compact building form, and ventilation-oriented façade design were analyzed. Hybrid approaches integrating rooftop photovoltaic systems with passive cooling and ventilated roof assemblies were examined for improving overall building energy performance under different climatic conditions.

**Results and Discussion:** The results indicate that climate-responsive passive strategies significantly reduce indoor heat gain and cooling demand, especially in warm and humid climates. Reflective and green roof systems effectively lower roof surface temperature, while phase change material-based elements shift peak thermal loads and enhance energy efficiency. Building compactness, façade shading geometry, and optimized airflow pathways were found to strongly influence energy consumption and often outperform high-cost mechanical solutions. Integration of passive cooling with photovoltaic systems further improved thermal and electrical performance of buildings.

**Conclusion:** The research demonstrates that low-cost net-zero energy performance can be achieved through intelligent climate-responsive design, optimized material selection, and integration of simple renewable energy systems. Adoption of these strategies can significantly reduce operational energy consumption, enhance thermal comfort, and promote sustainable and affordable building development across diverse climatic regions of India.

**Keywords: Net-Zero Buildings, Energy Efficiency, Active Strategies, Passive Strategies, Climate-Responsive Design, Sustainable Buildings**

# OP-112: Demographic Shift in Odisha: Trends, Challenges and Insights from Urban Odisha



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**Introduction:** Demography is the study of human population dynamics that examines population size, composition, and characteristics, and how they intersect with social, cultural, economic, ecological, and healthcare factors. According to the classic theory, increases in per capita income, industrialization, urbanisation, and overall socio-economic progress naturally contribute to lower birth and death rates, guiding populations toward stabilisation. This definition of demographic shift is observed as India has surpassed China in 2022 as the world's most populous country (UN DESA, policy brief No. 143). Then Odisha is amongst the slowest movers of urbanisation in India with less than 17% of its population living in less than 2% of land as per 2011 census. But Odisha is presently on a demographic shift, which means like the global population composition a major shift is taking place in Urban Odisha where population growth is more than its rural population. It means people are migrating to urban areas for better life or rural areas are naturally merging into urbanisation.

**Methods and Material:** This analysis relies entirely on secondary data sources, including the 2011 Census of India, recent rounds of the Sample Registration System (SRS), and the National Family Health Survey (NFHS). Key demographic indicators examined include Infant Mortality Rate (IMR), Under Five Mortality Rate (U5MR), Total Fertility Rate (TFR), Life Expectancy at Birth (LEB), Sex Ratio at Birth (SRB) and additionally, population projections have been conducted at the local level. The Monte Carlo Markov chain (MCMC) technique was used to get Bayesian estimates.

**Result and Discussion:** Cities are experiencing significant demographic change, a structural megatrend largely determined by natural and migratory factors, but sometimes also magnified by specific shocks such as pandemics, stress, natural disasters. Similarly states Infant Mortality Rate reached into a respectable status from the worst; while some of its industrial & mineral rich district along with state recorded sharp decline in total fertility rate; along with rise in elderly people. Another important outcome of the study observed in last two decades of family planning intervention amongst reproductive age groups i.e. youth, increase in educational level and more important the health infrastructure played a significant role in states achievement. Similarly NFHS-5 (2019-21) reports a 14% decline in Odisha's TFR to 1.8 since 2015-16, consistently lower than India's national average since 1990.

**Conclusion:** Odisha has been a subject of interest among demographers and planners for a considerable time due to its unique demographic situation. Odisha's remarkable success in reducing fertility has garnered international attention and admiration, especially given that it ranks among the poorest states in India in terms of per capita income and industrial output. Many demographers refer to this situation as a "demographic dilemma". Similarly Odisha's demographic transition poses challenges before policymakers are going to be huge; first disparity between rural urban population with aspirations; second dealing with declining fertility rate below natural replacement level and third increasing elderly population. Odisha's demography is currently seen globally in countries like Scandinavia i.e. Sweden, Norway, Denmark, Finland etc.

**Keyword:** *Demography, Migration, Urbanisation, Urban Planning, Governance.*

# OP-113: EXPERIMENTAL INVESTIGATION ON STABILISATION OF EXPANSIVE SOIL

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**Introduction:** Expansive soils undergo significant volume changes with variations in moisture content, leading to cracking, heaving, and damage to civil engineering structures. Conventional stabilization methods using cement and lime are widely practiced but pose environmental concerns due to high carbon emissions. This has led to increased interest in sustainable ground improvement techniques utilizing industrial by-products. This study explores the potential of geopolymerised fly ash as an eco-friendly stabilizer for expansive soil.

**Materials and Methods:** The expansive soil used in this study was collected from Bhubaneswar, Odisha. Class F fly ash was employed as the stabilizing material and activated using sodium hydroxide solutions of different molarities (10 M, 12.5 M, and 15 M) along with sodium silicate solution. Various liquid-to-solid ratios and fly ash contents were adopted, resulting in a total of 81 mix combinations. The prepared specimens were cured for periods of 3, 7, and 28 days and tested for unconfined compressive strength to evaluate the effectiveness of geopolymer stabilization.

**Results and Discussion:** The experimental results indicate a significant improvement in the strength characteristics of the treated soil compared to untreated soil. The unconfined compressive strength increased with curing duration due to progressive geopolymerisation. The maximum strength value of 4.8 MPa was achieved after 28 days of curing for the mix containing 12.5 M sodium hydroxide and a liquid-to-solid ratio of 1.25. Further increase in alkali concentration did not result in additional strength gain due to over-activation effects leading to microstructural imbalance. The findings also suggest that fly ash–based geopolymer stabilization is both economically viable and environmentally sustainable compared to conventional stabilizers.

**Conclusion:** The study demonstrates that geopolymerised fly ash is an effective and sustainable stabilizing agent for expansive soils. The formation of a dense geopolymer matrix significantly enhances the strength properties of soil, making this technique suitable for eco-friendly ground improvement applications.

**Keywords:** Expansive soil; Geopolymerisation; Fly ash; Unconfined compressive strength; Sustainable stabilization

# OP-114: ENERGY PERFORMANCE ANALYSIS OF BIM-BASED BUILDING MODEL USING REVIT, AUTOCAD AND eQUEST

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**Introduction:** Building Energy Modeling (BEM) is widely used to evaluate building performance and reduce energy consumption. With the advancement of Building Information Modeling (BIM), integrating design tools with energy simulation software has become essential. This study investigates the workflow of transferring a BIM-based building model from Autodesk Revit to Autodesk AutoCAD and finally to eQUEST for energy analysis. The objective is to assess how effectively eQUEST interprets CAD geometry for simulation.

**Materials and Methods:** A simplified IT building model was created in Revit and exported in DWG format. The drawing was cleaned in AutoCAD to remove unnecessary layers and ensure accurate footprint tracing. The processed file was imported into eQUEST, where shells and thermal zones were generated. Construction properties, glazing details, internal loads (occupancy, lighting, equipment), schedules, and HVAC system parameters were defined. A full 8760-hour annual energy simulation was conducted to estimate heating, cooling, and total energy consumption.

**Results and Discussion:** The results show that eQUEST can effectively use CAD-derived geometry when proper preprocessing is performed. However, manual adjustments are required for accurate zoning and envelope definition. Cooling load was found to dominate due to internal equipment and occupancy patterns typical of IT buildings. Envelope properties and HVAC system selection significantly influenced annual energy use. The workflow also revealed interoperability limitations between BIM and simulation platforms.

**Conclusion:** The Revit '! AutoCAD '! eQUEST workflow provides a practical and educational approach to understanding building energy modeling. Despite minor limitations in direct BIM integration, the process effectively demonstrates the relationship between building design parameters and energy performance, supporting energy-efficient building analysis.

**Keywords:** ***Revit, AutoCAD, eQUEST, Building Energy Modeling, Energy Simulation, HVAC Analysis, BIM Integration.***.

# OP-115: Substituting sugarcane bagasse, silica fume, and glass fibre for partially replaced cement: a strength study

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**Introduction:** Sugarcane bagasse ash (SCBA), a by-product of the sugar-making process, is a unique biomass incineration ash that can be used as a Supplementary Cementitious Material (SCM). This study delves into the mechanical properties and environmental impact of cement mortar when SCBA, silica fume (SF), and glass fibres (GF) are incorporated, thereby showcasing the potential of SCBA in waste resource management. The fibre-reinforced cementitious matrix was prepared by partially replacing cement with SCBA at 5%, SF at 10 and 15%, and GF at 1 and 1.5%. The experimental investigation evaluates fresh and hardened concrete for its compressive, flexural, and split tensile strength at 7 and 28 days.

**Methods and Materials:** This study utilized Grade 53 Portland Cement having an initial setting time and final setting time of 45 and 225 minutes, specific gravity (SG) of 3.12 and fineness modulus of 7.5 with different admixtures such as SCBA, Silica fume, and Glass fibers in varying ratios. The fine aggregates with a SG of 2.61 and water absorption rate of 0.8% were procured locally. 20 mm crushed granite angular aggregate with a SG of 2.72 and a water absorption rate of 0.45 % were used as coarse aggregate. With a SG of 1.08, Sika Visco flow-615 KE was used as the super plasticizer. Glass fibres 0.5 mm in diameter and 25 mm in length were procured. The glass fibers had a SG of 1.15, and tensile strength of 1500 N/mm$^2$.

**Results and Discussion:** Compressive strengths at 7 and 28 days fell within the range of 37 to 43 MPa. Notably, the addition of 5% SCBA, 10% silica fume (SF), and 1% glass fiber (GF) resulted in a significant strength enhancement, with increases of 3.5% at 7 days and 12.19% at 28 days compared to control mixtures. The flexure strength of the different mix ratios has grown in contrast to the control mix for both 7 days and 28 days, showing an average increase of 7% and 12%, respectively. Compared to the control mix, the split tensile strength increased by 8.77% for 7 days and 10.22% for 28 days at the 5% SCBA, 10% SF, and 1% GF replacement levels. An increase in 28-day strength was observed for SF at 10%.

**Conclusion:** The integration of 5% sugarcane bagasse ash, 10% silica fume, and 1% glass fiber significantly enhances the mechanical properties of concrete, achieving a peak 28-day compressive strength increase of 12.19% over the control mix. Beyond compression, this specific replacement ratio consistently improves durability, raising flexural and split tensile strengths by approximately 12% and 10.22% respectively. Consequently, using these industrial and agricultural by-products offers a viable path for waste resource management while producing a higher-strength, sustainable cementitious matrix.

**Keywords:** ***Sugarcane bagasse ash (SCBA), silica fume (SF), glass fibers (GF), Supplementary cementitious material (SCM).***

# Spatial Graph Convolutional Network for Hydrologically Connected Flood Susceptibility Modeling

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**Introduction:** Flood Susceptibility modeling in river basins requires understanding spatial dependencies and hydrological connectivity. Monsoonal flooding patterns in the Baitarani River Basin (BRB) are governed by local topographic key and drainage elements, as well as upstream-downstream interactions, drainage density, and surface connectivity. Physical properties that are highly correlated among fluvial deposits, will give rise to statistically non-independent samples when considered by standard classifiers. To address this structural problem, this paper presents a Spatial Graph Convolutional Network (GCN) framework that intrinsically considers the influence of neighborhoods in the graph-based learning for FS mapping.

**Methods and Materials:** A flood inventory for the BRB (2003-2023) was compiled using validated historical flood records. We created a balanced dataset of flood and non-flood areas in order to avoid sampling bias. In the conditioning factors, 12 conditioning surfaces representing topography, hydrology, climate, and land surface characteristics such as Elevation (E), Slope (S), Curvature, Aspect, among others: TWI, SPI STI.TRI rainfall intensity NDVI LULC. Atomic space elements were modeled as nodes in the graph and edges, representing first-order spatial adjacency ties, which maintained terrain connectivity. Feature matrices were normalized before any model building was performed. The GCN model stacked a number of convolutional layers to perform spectral graph convolutions on the normalized adjacency matrices with self-loops. To compare performance, similar training–testing split rates (70–30) were used to train SVM and Simulated Annealing-Optimized SVM (SA-SVM) models. The performance of the models was measured by AUROC.

**Result and Discussion:** The Spatial GCN obtained an AUROC of 0.93, outperforming SVM with 0.88 and SA-SVM with 0.91 respectively. The convolutional propagation enabled the model to learn the hydrological dependencies between adjacent cells, which conventional kernel-based classifiers are unable to capture. The better discrimination ability implies flood is more class-dependent on local spatial information other than feature vectors in isolation. Thus, by including graph-based learning the interpretation of flooding processes in fluvial environments is physically more consistent.

**Conclusion:** The constructed Spatial GCN model underpins a hydrologically aware and spatially explicit assessment of flood susceptibility in the BRB. It shows that graph-based deep learning is indeed promising in watershed-level hazard prediction compared to SVM and SA-SVM. This model provides a strong basis for zoning flood risks, planning infrastructure, and water resource management in the other Basins where data are lacking.

**Keywords:** Flood Susceptibility Mapping; Graph Convolutional Network; Spatial Deep Learning; Hydrological Connectivity; Baitarani River Basin; AUROC; GIS-Based Modeling

# OP-117: Investigating the Subarnarekha River Basin's Surface Runoff Using the ARC-SWAT Method

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**Introduction:** Water is the most abundant substance on Earth and is considered one of the most conspicuous and vital natural resources. It is a fundamental necessity for all living beings, particularly humans. The physical characteristics of a catchment—such as morphology, soil type, and land use—play a significant role in shaping the components of the water balance within that catchment. In recent times, developing nations like India have experienced considerable economic losses due to extreme weather events. These adverse occurrences are largely attributed to rapid population growth, urbanization, and elevated standards of living, which collectively contribute to significant variations in temperature and precipitation, thereby affecting the hydrological cycle. Climate change has exacerbated the imbalance in hydrological processes, leading to increased surface runoff, erratic rainfall patterns, floods, droughts, humidity fluctuations, and severe soil erosion. Therefore, climate variability must be considered a critical factor in the estimation of water availability.

**Methods and Materials:** The Soil and Water Assessment Tool (SWAT) is a kind of continuous and physically based conceptual model that works with the ArcGIS interface. This is a hydrological model which was developed in the early 1990s by the USDA Agricultural Research Service at the Blackland Research & Extension Centre, Texas, USA, for the Agricultural Research Service (ARS), basically for finding out its impact on land management practice, mostly in large and complex watersheds. SWAT performs a simulation process for various parts of the hydrological cycle, nutrient cycle, and sediment yield, and further it aggregates for each sub-basin. In the present study, SWAT 2012 is integrated with ArcGIS 10.2 software in order to perform a simulation of stream flow of the Subarnarekha River basin.

**Result and Discussion:** The SCS-CN method, along with the Arc SWAT model, was combined in order to simulate runoff of the Subarnarekha river basin for the period 2012-2022 on both monthly and yearly time steps, considering a one-year warm-up period. The simulation of the SWAT output was validated by plotting the observed and simulated data and calculating the value of the coefficient of Determination ($R^2$).

**Conclusion:** The present study was conducted over the Subarnarekha River basin as a watershed for runoff determination. The SWAT model with GIS interface has been chosen as a mathematical model in order to determine surface runoff of the Subarnarekha River basin. The model was executed using 10 years of precipitation data (2012–2022) along with corresponding minimum and maximum temperature records and other spatial datasets, as discussed earlier. The simulated discharge was validated against observed discharge using the coefficient of determination ($R^2$). The obtained $R^2$ values were 0.8068 and 0.9123 at monthly and annual time scales, respectively. These results indicate that the SWAT model can be considered one of the most reliable hydrological models for estimating surface runoff in watersheds, particularly in remote areas.

**Keywords*: SWAT, Land map, Soil map, surface runoff, $R^2$.***

# OP-118: Experimental And Numerical Investigation Of Flow Characteristics Over A Weir In Open Channel

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**Introduction:** Modified rectangular broad-crested weirs improve flow measurement accuracy and hydraulic efficiency. This study experimentally investigated the effect of weir positioning on parameters such as free surface profile, discharge coefficient (Cd), and velocity distribution under varying hydraulic heads. Experiments were conducted in a 10 m tilting flume using a SonTek FlowTracker2 (ADV) to measure three-dimensional velocities. Depth-averaged velocities were computed to analyze energy distribution and flow uniformity. A predictive regression model involving six dimensionless parameters was developed, yielding $R^2 = 0.91$. Low RMSE (0.00737), NRMSE (0.0588), MAPE (1.66178), and MAE (0.00588) values confirm strong accuracy and reliability.

**Materials and Methods**: The experimental investigation was carried out in a 10 m long, 0.6 m wide, and 0.7 m deep rectangular tilting flume under controlled laboratory conditions. A modified rectangular broad-crested weir was fabricated and installed at a predetermined location in the channel. To simulate realistic boundary conditions, uniform bed roughness was introduced using gravel materials characterized through sieve analysis (D50 determined). Discharge was measured using a calibrated flowmeter, and water surface elevations were recorded with a point gauge. Three-dimensional velocity components were measured using a SonTek FlowTracker2 based on Acoustic Doppler Velocimetry (ADV), operating at a sampling frequency of 10 Hz. Experiments were conducted for multiple discharges under subcritical and fully turbulent flow conditions. Depth-averaged velocities were computed using the trapezoidal integration method due to non-uniform measurement intervals. Key dimensionless parameters such as H/P, H/L, ho/H, Froude number (Fr), Reynolds number (Re), and B/H were evaluated. Multiple linear regression analysis was performed to develop a predictive model for the discharge coefficient (Cd).

**Results and Discussion:** The stage–discharge relationship at upstream sections followed a power-law trend with strong correlation ($R^2$ e" 0.90). Free surface profiles showed a noticeable backwater rise upstream of the crest and a sharp drawdown over the weir, indicating acceleration toward critical flow conditions. Velocity profiles confirmed boundary layer effects, with lower velocities near the bed due to no-slip conditions and peak velocities occurring toward the free surface. The regression model incorporating six dimensionless parameters yielded $R^2 = 0.91$, demonstrating strong agreement between predicted and experimental Cd values. Error analysis showed low RMSE (0.00737), NRMSE (0.0588), MAPE (1.66%), and MAE (0.00588), confirming high predictive reliability.

**Conclusion/Recommendation:** The modified broad-crested weir exhibited stable hydraulic performance and improved discharge characterization. The developed regression equation can be effectively applied for discharge estimation in open channel systems, and further studies may extend the analysis to different crest geometries and higher flow conditions.

**Key words:** ***Broad-crested weir, Discharge coefficient, Acoustic Doppler Velocimetry, Regression analysis, Open channel flow, Hydraulic modeling.***

# OP-119: PREDICTION OF GROUNDWATER LEVEL USING ANFIS, ANFIS-PSO & ANFIS-FFA APPROACH: A CASE STUDY

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**Introduction:** Groundwater is a critical natural resource that sustains agriculture, industry, and domestic needs, yet its availability is increasingly threatened by over-extraction and climate variability. Groundwater level prediction faces complex challenges in the sustainable management of groundwater as a vital resource. Predicting groundwater level is crucial for water resource management. Accurate prediction of groundwater levels is the initial stage in assessing overall water resources and their distribution. Accurate prediction of groundwater levels is therefore essential for effective resource management and long-term sustainability. Traditional statistical and numerical models often struggle to capture the nonlinear and complex interactions among hydro-climatic variables.

**Methods & Material**: This study introduces an innovative approach of machine learning for predicting groundwater level with improved accuracy using some machine learning models such as ANFIS, ANFIS-PSO and SVM-FFA. The intricate and nonlinear structure of groundwater systems frequently presents challenges for traditional hydrological models. On the other hand, machine learning (ML) techniques provide strong data-driven methods that can uncover links and patterns in big datasets. This work investigates machine learning techniques to improve the accuracy of groundwater levels predictions, which are constrained in conventional hydrological models. The study uses long time series of monthly data from 1995-2024 taking precipitation, temperature, and relative humidity as input features from Bhubaneswar block of Khordha district of Odisha, India. In this analysis, performance metrices like Mean Square Error (MSE), Coefficient of determination ($R^2$), and Nash Sutcliffe Efficiency (NSE) were employed.

**Results & Discussion**: It is found that the value of MSE, $R^2$, NSE are 0.4537, 0.9834, 0.9867; 5.6634, 0.9489, 0.9521 and 15.8965, 0.8941, 0.8993 in case of ANFIS-FFA, ANFIS-PSO and ANFIS respectively. The results reveal that the ANFIS-FFA models perform significantly better in enhancing their accuracy and robustness. The suggested model demonstrated good predictive accuracy and strategic flexibility, making it an effective choice for predicting groundwater levels.

**Conclusion**: The study shows that using the ANFIS-FFA approach makes groundwater level prediction more reliable and accurate. ANFIS combines the strengths of fuzzy logic and neural networks, while the Firefly Algorithm helps fine-tune the model for better performance. Together, they create a system that can handle the complex and changing factors that affect groundwater. The improved results mean that this method can be a useful tool for managing water resources, helping decision-makers plan more effectively and ensure sustainable use of groundwater in the future.

***Keywords:*** *Ground Water Level, ANFIS, ANFIS-FFA, ANFIS-PSO*

# OP-120: Land Suitability Assessment for Urban Spatial Growth using Integrated MCDM and GIS Techniques: A Study of Bhubaneswar, India

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**Introduction:** Urbanization is a key driver of city formation, leading to spatial expansion along urban corridors and the transformation of rural fringes into built-up areas. In India, rapid population growth and rural-to-urban migration have resulted in unplanned urban sprawl, creating significant planning challenges. Identifying suitable areas for future development is therefore essential for sustainable land management. Land suitability analysis, commonly conducted using Geographic Information system (GIS) integrated with Multi-Criteria Decision Making (MCDM) techniques, provides a systematic basis for informed planning. However, previous studies on Bhubaneswar have been confined to municipal limits, neglecting the wider Bhubaneswar Development Planning Area (BDPA). This study addresses this gap by analyzing urban growth dynamics across the entire BDPA and identifying key drivers of future expansion.

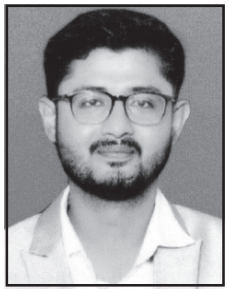
**Materials & Methods:** The study area is situated in the Khordha district of Odisha, India. A total of thirteen criteria were selected to assess urban growth suitability. The primary spatial criteria considered for analysis include slope, elevation, soil characteristics, aspect, geology, geomorphology, proximity to roads, land use/land cover (LULC), distance from streams, depth to water table, proximity to existing built-up areas, distance from eco-sensitive areas, and population density. Standard geospatial pre-processing techniques, including geo-referencing, digitization, and reclassification, were employed to generate thematic layers. These layers were subsequently integrated and overlaid using modelling tools and MCDM approaches to evaluate land suitability and analyze spatial patterns of urban expansion.

**Results & Discussion:** The analysis reveals that the most significant determinants of urban expansion are distance to roads, LULC, distance to existing built-up areas, slope, and population density. Model validation using the Receiver Operating Characteristic curve produced Area under the Curve values of 0.89 for the Analytical Hierarchy Process model and 0.86 for the Best Worst Method model, demonstrating strong predictive capability and overall model robustness. The results further emphasize the necessity for strategic and evidence-based planning interventions, particularly in the western and eastern peripheral zones of the Bhubaneswar planning region, which are predominantly characterized by forested landscapes and agricultural land uses, respectively. Furthermore, the future scope of the research is promising, particularly with respect to the integration of advanced machine learning algorithms to enhance the predictive accuracy and robustness of the model.

**Conclusion / Recommendation:** This hybrid approach will be instrumental in addressing the challenges of sustainable urban development in a fast-evolving world. This study can be very helpful to the planners, Policy makers and authorities in formulation of strategies/policies and suggesting model-based approach for guiding future planned development in my study area that accommodate the needs of a growing population while preserving the environment and enhancing overall quality of life.

**Keywords:** ***Land suitability assessment, MCDM, Urban Growth, Geographic Information System, built-up areas.***

# OP-121: Investigation of Flow Behaviour in an Open Channel with Submerged Porous Rigid Bed and Mixed Vegetation



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**Introduction:** Understanding flow behaviour in open channels is essential for the design and management of irrigation canals, drainage systems, flood control structures, and river restoration projects. Natural channels often consist of porous beds and vegetative elements that significantly influence velocity distribution, turbulence characteristics, resistance to flow, and sediment transport. However, limited studies are available on the combined effect of submerged porous rigid beds and mixed vegetation. This study aims to investigate the hydraulic behaviour of flow in an open channel with a submerged porous rigid bed and mixed vegetation, focusing on velocity variation, turbulence modification, and flow resistance characteristics.

**Materials and Methods:** The experimental investigation was conducted in a laboratory flume under controlled steady flow conditions. A rigid porous bed layer was installed along the channel bottom, and mixed vegetation elements of varying density and arrangement were introduced above the bed. Discharge was regulated using a flow control system, and depth measurements were recorded using point gauges. Velocity measurements at different vertical and longitudinal sections were obtained using Flow Tracker (ADV). The experimental parameters included variation in discharge, vegetation density, and submergence ratio. Flow characteristics such as velocity profile, Reynolds number, friction factor, and energy loss were analyzed to evaluate the interaction between porous media and vegetation.

**Results and Discussion:** The results indicate that the presence of a submerged porous rigid bed significantly alters the near-bed velocity distribution due to enhanced resistance and energy dissipation. Mixed vegetation further modifies the flow structure by reducing mean velocity and increasing turbulence intensity within the vegetative zone. A reduction in overall flow velocity and an increase in flow resistance were observed with increasing vegetation density. The combined effect of porous bed and vegetation resulted in improved flow retardation compared to non-porous and non-vegetated conditions. The velocity profile exhibited a non-linear distribution, especially within the vegetative layer, indicating strong momentum exchange between flow layers. These findings highlight the complex interaction between porous substrate and vegetative elements in regulating open channel flow.

**Conclusion:** The study demonstrates that submerged porous rigid beds combined with mixed vegetation significantly influence flow behaviour by increasing resistance and modifying velocity distribution. Such configurations can be effectively utilized in eco-hydraulic engineering applications such as riverbank stabilization, erosion control, and sustainable channel design. Further studies may focus on sediment transport and numerical modeling for comprehensive understanding.

**Key words:** Open Channel Flow, Porous Rigid Bed, Mixed Vegetation, Flow Resistance,

# PP-122: Utilization of Fly Ash and Alccofine in Sustainable Concrete for Enhanced Strength and Durability

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**Introduction:**

Concrete occupies unique position in modern construction industry due to its versatility, strength, and durability. Additionally, the production of cement emits carbon and consume a large quantity of energy which affects the environment to a great extent. The Concrete performance can be enhanced and sustainable by partially replacing cement within a permissible percentage, with fly ash and Alccofine. Research has been conducted on the use of fly ash, volcanic ash, volcanic pumice, pulverized-fuel ash, blast slag and alccofine as cement replacement material. Fly ash and others are pozzolanic materials because of their reaction with lime liberated during the hydration of cement. These materials can also improve the durability of concrete and the rate of gain in strength and can also reduce the rate of liberation of heat, which is beneficial for mass concrete.

**Materials and Methods:**

The mix design was followed through as per Indian Standard (IS) guidelines. The cement was replaced partially with fly ash ranging from 5% to 30%. Additionally, a portion of fly ash was replaced with Alccofine in the range of 5% to 30% to study its impact on strength characteristic. The super plasticizer helped for compensating the loss in early age strength by reducing the water cement ratio and increasing the workability of the mix. The specimens were casted and tested for different curing periods, with focus on 28-days compressive strength.

**Results and Discussion:**

The test results showed that utilization of fly ash improved workability and contributed to long-term strength gain due to its pozzolanic activity. The use of Alccofine further enhanced the microstructure by filling voids and accelerating hydration, which results for early strength reduction commonly observed in fly ash concrete. Based on the various combinations studied, the mix containing 30% fly ash cement replacement and 8% Alccofine replacement with the fly ash, achieved the target 28-day compressive strength. The results indicate a combined effect of fly ash and Alccofine enhance strength characteristics while fostering sustainable material utilization.

**Conclusion:**

The investigation shows that replacing cement with fly ash and Alccofine partially can produce concrete with satisfactory strength and improved performance while reducing cement consumption. The optimum combination identified was 30% fly ash replacement with 8% Alccofine substitution, which achieved the required 28-day strength. The utilization of such supplementary materials contributes to sustainable construction practices by lowering environmental impact and enhancing durability properties. This approach can be effectively adopted in structural and mass concrete applications.

**Keywords:** Concrete, Fly Ash, Alccofine, Pozzolanic Materials, Sustainable Construction, Compressive Strength

# PP-123: A Sociological Study on Work Culture and Livelihood Pattern of Gig Workers of Gig Economic Sectors in Bhubaneswar City, Odisha

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**Introduction:** Today India stands at a critical policy juncture, as technology enabling job opportunities as well as start-up ecosystem for Indian youths as well as those seniors in society like to remain engaged through digital identity systems like Aadhar and e-shram. Gig and platform-based jobs are becoming a major contributor to the major workforce of the urban job market while providing daily convenience and on-demand services as the number is ever growing. The gig workers are the food delivery agents, app-based technicians, warehouse runners, and on-demand service providers.

**Methods and Material:** The study involved both secondary as well as primary inputs relating to Gig Workers including desktop review various policy options across the globe. According to Niti Ayog's study (2020-21) we have over 7.7 million workers engaged in the gig economy and projected to be near 23.5 million (2029-30). The study uses characteristics such as location (in urban areas), age group (18-45), education levels (ranging between secondary school and education), income level (below 75th percentile earning below Rs.15,000), ownership of mobile phones and access to bank account for estimating the gig and platform workers. As part of the study, I have conducted a sample survey of Gig Workers to understand their trends, challenges, opportunities.

**Result and Discussion:** The study observes economic forces and maintaining proper demand and supply chain are revitalizing worker's wage and offer subsidies to help support their livelihoods. Lessons from South Korea observed that rest rooms and replenishment places offered essential amenities such as clean drinking water, phone charging station, and comfortable seating areas so that the gig workers can hydrate, cool down and reduce their fatigue from navigating traffic and harsh weather. Singapore passed a law protecting the gig worker's right under Platform Workers Act, getting higher Central Provident fund (CPF) contributions. According to the International Labour Organization (ILO), ISSA, OECD, it speaks on adequate pay, working time regulation, occupational safety and health, employment protection citing examples of the United Kingdom, Spain and China. The monotax mechanism, access to sickness, maternity and disability benefits as well as old-age pension and other benefits like adoption of Social Security Council Organization (SOCSO) with PPP (Public Private Partnership) in collaboration with the Service providing Platforms in different countries(Indonesia, France, Argentina, Malaysia, Germany and Uruguay).

**Conclusion:** This research portrays the intervention of Public-Policy led urban plan model architecture. The model adepts to real-time changes and addresses dynamic problems. Rewiring the employment framework with ongoing schemes such as PMSYMY (PM Shram Yogi Maandhan Yojna), ELI (Employment Generation Scheme), and to onboard the unregistered workers and robust data sharing between the Government and Private employer, to better allocate the resources. OnboardàSkill upàRepresent.

**Keyword:** *gig workers, Youth, Public Policy, Urban Planning, CSR, PMSYMY.*

# PP-124: Children's Active Mobility to School: Evidence from Neighbourhoods of Bhubaneswar

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**Introduction:** Active mobility is foundational to sustainable urban transportation, yet the spatial relationship between students and schools in India has fundamentally shifted. The evolution from the co-located, residential Gurukul system to the centralized Prussian-style classroom—institutionalized by Macaulay (1835)—created the necessity for the daily commute. While walking and cycling were historically dominant, recent decades have witnessed a sharp modal shift toward motorized transport, driven by aggressive motorization and deteriorating pedestrian safety. This transition has transformed the school run into a critical urban challenge. Consequently, this research analyzes the utilization of active mobility by students within the neighborhood context. It investigates the infrastructure-behavior nexus, aiming to identify how supporting infrastructure can reshape the urban ecology to restore a safe, accessible, and independent commuting environment for students.

**Methods and Material:** Adopting a concurrent mixed-methods framework, this study triangulates quantitative mobility metrics with qualitative behavioral insights. Primary surveys capture modal splits, commute distances, and peak-hour vehicular dynamics, while perception questionnaires assess parental safety concerns and escort decisions. Simultaneously, neighborhood spatial audits evaluate land-use patterns to identify opportunities for infrastructure optimisation, such as retrofitting parking and enhancing pedestrian networks. This comprehensive approach contextualises physical traffic flows within the social constraints of the "school run," justifying evidence-based interventions to restore safe, active mobility.

**Result and Discussions:** Analysis reveals a critical spatial paradox: while 60% of students reside within a cyclable 2-3 km radius, passive motorised modes dominate, evidencing a severe distance-mode mismatch. This reliance precipitates congestion, where unregulated on-street parking encroaches on pedestrian infrastructure, triggering frequent vehicle-pedestrian conflicts. However, neighborhood spatial audits identified latent land parcels capable of absorbing 90% of peak parking demand. The research argues that retrofitting these off-street facilities is not merely a logistical fix, but a fundamental safety intervention. By reclaiming street space from stationary vehicles, the urban environment can be re-engineered to support active mobility, effectively aligning physical infrastructure with the proximity of the student population.

**Conclusion:** To resolve the "spatial paradox" of high proximity yet low active mobility, this research proposes a localized intervention framework aligned with the Odisha Urban Parking Policy and Bhubaneswar Street Design Guidelines. The strategy pivots on shifting the urban function of school zones from "vehicle storage" to "safe mobility corridors," leveraging specific state mechanisms to reclaim public space for students.

**Keyword:** *Active mobility, Gurukul system, Prussian-style classroom, infrastructure-behavior nexus, concurrent mixed-methods framework, neighborhood spatial audits, spatial paradox, passive motorised modes, vehicle-pedestrian conflicts*

# PP- 125: Compressive strength of Sustainable Mortar Using Industrial By-Products and Natural Fibre

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**Introduction:** The growing demand for sustainable construction materials has encouraged the replacement of conventional mortar constituents with eco-friendly alternatives. Fly ash and crusher dust serve as viable substitutes for cement and natural sand, respectively, while coir fibre enhances crack resistance and ductility. An initial optimization using the Taguchi L9 ($3^3$) method evaluated fly ash (10–30%), coir fibre (0.1–0.3%), and water–binder ratio (0.40–0.50), with crusher dust fixed at 35%. Several Taguchi-based mixes exhibited inadequate early-age strength due to higher fly ash content, increased water–binder ratios, and fibre-induced void formation. Therefore, revised mix designs were developed to enhance early-age compressive strength performance.

**Materials and Methods:** Ordinary Portland Cement (43 grade) was partially replaced with 10% fly ash in the revised mixes. Crusher dust replaced natural sand at two levels: 10% (Mix 1) and 15% (Mix 2). Coir fibre content was restricted to 0.1% to minimize voids and maintain workability. A controlled water–cementitious ratio ensured proper compaction and hydration. Mortar cubes were cast, vibrated for uniform compaction, water cured, and tested for compressive strength at 3 days. Three specimens were tested for each mix to determine average strength values.

**Results and Discussion:** Mix 1(10% crusher dust) achieved compressive strengths of 25.58 MPa, 37.39 MPa, and 29.52 MPa, with an average of 30.83 MPa. Mix 2 (15% crusher dust) recorded 34.44 MPa, 25.58 MPa, and 42.31 MPa, yielding a higher average strength of 34.11 MPa with testing 3 days of curing. The improved performance is attributed to better particle packing, enhanced aggregate interlocking, reduced porosity, and controlled fibre dosage. Mix 2 exhibited superior strength due to improved micro-filler effect and optimized gradation from increased crusher dust content.

**Conclusion:** The study confirms that while Taguchi optimization reduces experimental effort, critical evaluation is necessary for sustainable mortar systems. The revised mix design significantly enhanced early-age strength performance. Mix 2 showed the highest compressive strength and is recommended for further evaluation. The maximum strength specimens from Mix 1 and Mix 2 will be tested at 28 days to assess long-term strength development and durability performance. Balanced material proportions are essential for developing structurally viable and environmentally sustainable mortar.

**Keywords: Sustainable Mortar, Taguchi Method, Fly Ash, Crusher Dust, Coir Fibre, , Compressive Strength**

# PP-126: Waste-to-Resource Approach: Valorization of Water Treatment Plant Sludge and Fly Ash for Eco-Friendly Brick Production

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**Introduction:** Rapid urbanization has significantly increased the demand for construction materials, particularly burnt clay bricks, leading to excessive soil excavation and environmental degradation. Simultaneously, large quantities of sludge generated from water treatment plants and fly ash produced from thermal power plants pose serious disposal and environmental challenges. This study explores the feasibility of utilizing water treatment plant sludge incorporating fly ash in the manufacturing of sustainable bricks. The objective is to develop eco-friendly, cost-effective, and structurally viable bricks while promoting waste valorization and reducing dependency on conventional clay resources.

**Materials and Methods:** Water treatment plant sludge was collected, dried, and pulverized to achieve uniform particle size. Class F fly ash was used as the primary binding and pozzolanic material. Various mix proportions of sludge and fly ash were prepared to determine the optimum combination for strength and durability. A small percentage of cement was added as a stabilizing agent where required. The mixture was homogenized, molded into brick specimens, and cured under controlled conditions. Laboratory tests including compressive strength, water absorption, bulk density, and efflorescence were conducted as per relevant Indian Standard procedures to evaluate performance characteristics.

**Results and Discussion:** The experimental investigation revealed that bricks containing an optimal proportion of sludge and fly ash achieved satisfactory compressive strength suitable for non-load bearing and certain load-bearing applications. Water absorption values were within permissible limits, indicating adequate durability. The incorporation of fly ash enhanced pozzolanic reactions, improving bonding and reducing porosity. Additionally, the production process eliminated the need for high-temperature kiln firing, thereby reducing carbon emissions and energy consumption. The study demonstrates that sludge-based fly ash bricks can serve as a sustainable alternative to traditional burnt clay bricks while simultaneously addressing waste management issues.

**Conclusion:** The research confirms the technical feasibility of manufacturing eco-friendly bricks using water treatment plant sludge and fly ash. The developed bricks exhibit acceptable mechanical and durability properties, contributing to sustainable construction practices. This approach promotes circular economy principles by converting industrial and municipal waste into value-added building materials. Further research may focus on long-term durability assessment and large-scale production feasibility.

**Keywords:** ***Water Treatment Sludge, Fly Ash, Sustainable Bricks, Waste Utilization, Eco-friendly Construction Materials***

# PP-127: Comparative Analysis of Corrugation Orientation on the Seismic Performance of Corrugated Steel Plate Shear Walls (CoSPSWs)

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**Introduction:** Steel Plate Shear Walls (SPSWs) have emerged as a technologically advanced alternative to traditional RC systems. Corrugated Steel Plate Shear Walls (CoSPSWs) have emerged as highly efficient structural systems due to their superior strength-to-weight ratio and energy dissipation capacity. Unlike traditional flat plates, which often suffer from premature buckling, trapezoidal corrugations provide the out-of-plane stiffness necessary for high-performance seismic design. This study investigates the influence of corrugation orientation (vertical vs. horizontal) with a depth of 20mm on the structural behavior of CoSPSWs using nonlinear static (pushover) analysis in ABAQUS.

**Methods and Materials:** The numerical investigation was conducted using ABAQUS to develop a finite element (FE) model of a single-story Corrugated Steel Plate Shear Wall (CoSPSW) with an aspect ratio of 1.33 (2.0 m×1.5 m), supported by a boundary frame of HEB160 steel sections. The modeling process utilized S4R shell elements with a refined 20 mm mesh density, incorporating a double-flange welding simulation for effective load transfer and a lateral displacement of 70 mm for pushover analysis. Materials followed structural standards: HEB160 members and 0.8 mm infill plates having yield strength 400 MPa and 280 MPa respectively, validated against Alavi (2013). To assess geometric influence, two distinct specimens having a depth of 20 mm were evaluated, varying by corrugation orientation (vertical vs. horizontal) based on the trapezoidal profiles established by Zhao (2017).

**Results and Discussion:** Pushover analyses reveal that vertical corrugation significantly outperforms horizontal configurations in load-bearing capacity and buckling control. At a 20 mm depth, vertical orientation achieves a 69% higher yield load. While horizontal corrugations promote a more uniform lateral stress distribution and higher initial stiffness i.e. 16% greater initial stiffness than the vertical orientation, they are prone to global buckling. In contrast, vertical folds localize deformation along crests and troughs, fostering stable diagonal tension fields and superior energy dissipation.

**Conclusion:** This study concludes that vertical corrugation is the optimal orientation for seismic-resistant design, particularly when paired with trapezoidal profiles. Vertical alignment effectively delays global buckling and maximizes post-yield performance, offering a superior balance of strength and ductility. Although shallower horizontal plates provide a slight edge in initial elastic rigidity, they lack the robust post-buckling resistance observed in vertical systems. Consequently, utilizing deeper, vertically oriented corrugated infill plates provides a more reliable mechanism for energy dissipation and structural integrity in high-performance steel shear walls.

**Keywords:** ***Corrugated Steel Plate Shear Walls (CoSPSWs), Pushover Analysis, Corrugation Orientation, Seismic Performance, ABAQUS, Structural Stiffness.***

# PP-128: Parametric Investigation of Chord Spacing in Cold-Formed Steel Battened Columns under Axial Loading

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**Introduction:** This research work aims to analyze the axial behavior of cold-formed steel (CFS) battened columns using finite element analysis in ABAQUS 2020. The parametric analysis is carried out to assess the influence of chord spacing on buckling performance and load-carrying capacity. The batten spacing ranged from 0 mm to 40 mm, and the maximum strength of 32.5 kN was achieved at 40 mm spacing. The zero-spacing resulted in early local buckling and reduced peak load capacity. The research work also compares flat and hooped battens to identify various buckling modes and failure mechanisms. Geometric imperfections (10%) were also considered, and it is found that there is a 5% reduction in peak load capacity, resulting in more realistic and optimized column designs.

**Methods and Material:** The structural components were modeled using S280GD+Z, a galvanized, cold-formed steel characterized by a high strength-to-weight ratio. A batten column is simulated using finite element analysis. The column length is 2200 mm, and the depth of a web and the flange width may be 100 mm and 30 mm correspondingly. This section has uniform wall thickness = 1.25 mm. To represent a rigid connection at the base, an encastre boundary condition was applied to the bottom of the column. The loading is applied at the top end via a displacement-controlled loading condition. Nonlinear static analysis is performed on 3 configurations of chords placement (0 mm, 20 mm and 40 mm). To accurately capture the structural response under load, geometric nonlinearity was considered in all simulations.

**Result and Discussion:** The nonlinear static analysis revealed that chord spacing significantly influences the axial performance of CFS battened columns. An increase in chord spacing improved both initial stiffness and overall load-carrying capacity. Force displacement results displayed a gradual increase in stiffness and capacity to bear load as the spacing among chords increased. Initial stiffness and the peak load are the largest in 40 mm spaced and amounted to 32 kN and 20 mm 26 kN and 0 mm 17kN. Closely spaced chords are more prone to local buckling. Mesh convergence study validated that the 10×10 mm mesh captured accurate stress gradients and local instability patterns.

**Conclusion:** ABAQUS is used to develop highly sophisticated nonlinear finite element analyses to predict the behaviour of the proposed column system subject to static loading. The static analysis shows that the 40mm chord spacing is the suitable one among the three and can withstand upto 33kN load. Overall, optimized chord spacing enhances strength and stiffness of CFS battened columns.

**Keywords:** ***Cold-Formed Steel (CFS), Finite Element Analysis (FEA), Battened column, Load carrying capacity.***

# PP- 129: An efficient urban water management practice based on optimum LPCD estimated using the MLR-GA optimization approach

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**Introduction:** Dry and semi-arid regions of the world witness a decrease in freshwater supply due to urbanization and population growth. Effective water utilization and management is at the nexus for overcoming water scarcity. Limited research has concentrated on the end-user water study and its ideal solution, suggesting the necessity for research encompassing the end user's viewpoint for effective water management. The proposed study adopts a novel approach to determine the optimum daily per capita demand by implementing the Genetic algorithm (GA). The multi-linear regression (MLR) model is applied to data from the socioeconomic household survey to perform the optimization. A household survey in the Jaipur Municipal Corporation region was conducted to validate the proposed study.

**Methods and Materials:** This study utilizes survey data from 2,200 households in Jaipur to model water demand using Multiple Linear Regression. The primary fitness function, Y = 469.40 + 0.539(X1) - 0.026(X2) + 0.301(X3), along with three partial constraint equations (Y1, Y2, and Y3), was processed via the MATLAB Optimization Toolbox (R2019b). While the daily water demand is the dependant variable (Y), household water supply (X1), household area (X2), and annual household income (X3) are the independent variables. Genetic Algorithm (GA) optimization was applied to find minimized LPCD values, benchmarked against current standards.

**Results and Discussion:** Analysis revealed a strong correlation between household size and demand, despite a weak supply-demand association. While 34.47% of households have surplus supply, the optimized zone-wise values—ranging from 106.62 to 131.52 LPCD—are consistently lower than the government-mandated 133.66 LPCD.

**Conclusion:** This study addresses the critical challenge of urban water scarcity in India, where per capita freshwater availability is projected to drop to 1140 $m^3$ by 2050. By implementing a hybridized Multiple Linear Regression-Genetic Algorithm (MLR-GA) tool, the research successfully optimized zone-wise water demand for Jaipur, revealing that actual requirement (106.62–131.52 LPCD) are consistently lower than the government standard. These findings provide a framework for redesigning the distribution network to minimize wastage and enhance efficiency through a consumer-centric perspective. This optimization framework study provides a scalable model for developing water-sensitive distribution networks, ensuring sustainable urban governance and judicious use of our limited water resources.

**Keywords:** ***Water scarcity, Urban water management, Multiple Regression Analysis, Genetic Algorithm.***

# Evaluation of Tensile and Moisture Characteristics of Sabai Grass Fiber for Sustainable Wall Panel Applications

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**Introduction:** Sustainable construction has gained a lot of attention because of the environmental problems linked to using synthetic reinforcing materials Natural fibers are emerging as viable and sustainable alternatives owing to their biodegradability, renewability, and widespread availability. Sabai grass, which is found in many parts of eastern India, exhibits relatively high tensile strength along with low density however, its hydrophilic nature leads to significant moisture absorption, which adversely affects its long-term durability. Even though using alkali treatment is common to improve the properties of natural fibers, there aren't many studies that carefully look at how different concentrations of KOH affect both the tensile strength and moisture absorption of Sabai grass fibers. To fix this problem, the study looks at how different levels of KOH treatment affect the strength and physical properties of Sabai grass fibers. Experimental results show that treating with 7% KOH gives the highest tensile strength of 168.67 MPa, and using 5% KOH leads to the lowest water absorption of 95.26%, showing that controlled alkali treatment works well.

**Methods and Materials:** Sabai grass were treated with alkali using different concentrations of KOH solution (3%, 5%, 7%, and 9%). Untreated fibers were maintained as the control group for comparison. Tensile testing of individual fibers was conducted using a Universal Testing Machine, and the tensile strength (ó) was calculated using ó = P/A, where P represents the ultimate load and A denotes the measured cross-sectional area of the fiber. Water absorption tests were conducted by immersing the specimens in water under controlled conditions, and the percentage increase in weight was calculated to determine moisture absorption.

**Result and Discussion:** When fibers were tested for water absorption, it was observed that untreated fibers absorbed the maximum moisture at 163.11%, while fibers treated with 5% KOH absorbed significantly less at 95.26%, demonstrating improved dimensional stability. Furthermore, alkali treatment substantially enhanced tensile strength; untreated fibers measured 132.36 MPa, whereas treatment with 7% KOH yielded the highest strength at 168.67 MPa. However, a slight drop to 145.48 MPa at the 9% treatment level indicates potential surface degradation from excessive alkali exposure. The results show that using a controlled amount of alkali treatment helps improve the mechanical strength and makes the material less likely to be affected by moisture.

**Conclusion:** The research shows that treating Sabai grass fibers with alkali has a big effect on their strength and how they behave physically. Optimal results were achieved at specific concentrations, with 5% KOH providing the best moisture resistance (95.26%) and 7% KOH yielding the maximum tensile strength (168.67 MPa).The results show that treated Sabai grass fibers can be a good, eco-friendly reinforcement material for epoxy-based composite wall panel applications in sustainable construction.

**Keywords:** ***Sabai Grass Fiber, Alkali Treatment, Tensile Strength, Water Absorption, Sustainable Materials***

# OP-131: Effect of the size of mixing tube on air ingression and outlet temperature by an Infrared Suppression (IRS) Device

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**Introduction:** Infrared radiation suppression is one of the methods to protect the ships and fighter jets from external threats such as heat-seeking missiles. The infrared radiation (IR) is emitted from the hot expelled gas of the prime movers such as gas turbines, when they release the hot gas into the ambient condition typically in the infrared range (3 $\mu m$ to 5 ), making them venerable to the external threats. For safe operation of the fighter jets and ships, IR needs to be reduced, if not completely eliminated. This technology falls under the purview of Infrared stealth technology, which is a hot research topic among the scientists. The infrared suppression device essentially reduces the bulk temperature of the hot expelled gas by entraining cold ambient air and mixing it with hot gas. Infrared suppression device is a critical component of the modern ships and fighter jets, as it passively entrains cold air to attenuate the infrared radiation. In this work, we varied non-dimensional length of the mixing tube in the range of 0.5 to 5 to investigate its impact on the air entrainment and overall outlet temperature.

**Methods and Material:** The IRS Device consists of a set of co-axial cylindrical funnels made of steel. The hot gases flowing through them are taken as ideal gases for ease of computation. The authors use Ansys Fluent R 20. This employs finite volume method. Continuity, Reynolds Averaged Navier Stokes Equations and energy equations have been used for studying the effect of mixing tube length on air ingression and outlet temperature.

**Result and Discussion:**

It is observed that the air entrainment contiously increases with higher length of the mixting tube. For example, the dimensionless mass ingression improves by 72.59% and the outlet temperature decreases by 23% as compared to the inlet temperature,.as the mixing funnel becomes 5 times longer than its refrence value. But when the lengh of the mixing tube is made half of its reference value, then mass ingression declines by 15.77% as compared to its reference value. It is interesting to note that the slope of the air ingression plot drops gradually as the mixing tube become longer, which suggests the existence of an optimum length of the mixing tube corrosponding to the Reynolds number and nozzle injection temeprature.

**Conclusion:** It has been observed that a long mixing tube entrains more air than a short one. The higher air ingression and lower outlet temperature of a long mixing tube is supported by the strong axial low pressure created inside the IRS device.

***Keywords:*** *Infrared suppression, turbulence, cylindrical funnel, mixing tube*

# OP-132: Development and Demonstration of an effective bulletproofing glass using numerical simulation and experimental validation.

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**Introduction:** The development of composite bulletproof glass involves several key advancements in material science and engineering. Bulletproof glass, ballistic glass is designed to absorb and dissipate the energy of projectiles to prevent penetration. Bulletproofing glasses are mostly used for Military and Law Enforcement Vehicles, Banks and Jewelry Stores, Public Buildings and Embassies, VIP and Presidential Protection.

**Materials and Method:** Laminated Glass: Laminated glass is made up of multiple layers of glass bonded together with a plastic layer, typically polyvinyl butyral (PVB). The plastic layer helps absorb the energy from the impact and prevents the glass from shattering. Polycarbonate: Polycarbonate is a strong, tough plastic that is often used as one of the inner layers in composite bulletproof glass. It has high impact resistance and can stop bullets effectively by spreading out the force of the impact. Acrylic: Acrylic is another transparent plastic that is sometimes used for lightweight bulletproof applications. It is often combined with other materials like polycarbonate for added strength. Aramid Fibers (e.g., Kevlar): These high-strength fibers are used in some bulletproof glass composites to enhance impact resistance. Kevlar is known for its high tensile strength and is commonly used in armor applications. Glass Fiber Reinforced Plastics: Some composite materials incorporate glass fibers or other reinforcement materials to further increase the strength and rigidity of the glass.

**Result and Discussion:** Traditional bulletproof glass is very heavy. New advancements in materials, like advanced polycarbonate and carbon fiber composites, aim to reduce weight without sacrificing protection. Existing bulletproof glasses are opaque most of the time. Bulletproof glass, especially when used in vehicle windows or building facades, must maintain optical clarity. Manufacturing methods need to be designed for improving the lamination processes to ensure that the glass remains clear even with multiple layers. The thermal aspects of existing bulletproof glass are not well defined. This study is needed for the use of vehicles in different weather zones for energy efficiency. Emerging technologies need to be explored integrating electronic systems into bulletproof glass, such as adding sensors to detect impacts or even self-healing capabilities that can repair minor damage.So, we will create a light weight cost-effective and highly durable bulletproofing glass using numerical simulation and experimental validation. Collecting data during Possessing flexibility to provide sufficient comfort and evaluating parameters such as energy consumption and subjective questionnaires could provide valuable outcomes. We will also perform Compressive strength and fatigue analysis.

**Keywords:** Bulletproof glass, ballistic glass, polyvinyl butyral (PVB), Aramid Fibers (e.g., Kevlar), advanced polycarbonate and carbon fiber composites.

# OP-133: Hybrid Optimization of Laser Drilling for Al 6063: Integrating Taguchi Design with Machine Learning for Predictive Parameter Control

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**Introduction:** In response to the rising complexity of laser material processing, machine learning is utilized to model the intricate, non-linear relationships between process parameters and material quality. Critical performance metrics, including Material Removal Rate and Heat Affected Zone size, are predicted through data-driven methodologies. By replacing traditional, expensive trial-and-error experimentation with high-dimensional optimization models, the parameter space is effectively probed and analyzed. These surrogate models are trained directly on experimental datasets, allowing for rapid virtual experimentation and process optimization. A significant reduction in time-consuming physical testing is achieved, while the high predictive accuracy required for advanced manufacturing is maintained. Consequently, the underlying input-output relationships are mastered to ensure unmatched operational precision.

**Materials and Method:** To optimize fiber laser drilling on Aluminium 6063, a magnesium-silicon alloy valued for its extrudability, a hybrid methodology combining Taguchi techniques and machine learning is implemented. Specially prepared 1.2 mm thick specimens are utilized to analyze the non-linear interplay between engraving inputs and process outputs. By integrating Taguchi L25 Orthogonal Arrays with Multiple Linear Regression, critical metrics such as Material Removal Rate (MRR) and Heat Affected Zone (HAZ) size are evaluated within a multi-objective framework. This data-driven approach allows for the establishment of an optimal parameter framework, effectively replacing expensive trial-and-error experimentation. Consequently, physical testing is significantly reduced while the high operational precision necessary for aerospace and automotive structural applications is maintained.

**Result and Discussion:** In this study, a hybrid optimization framework utilizing Signal-to-Noise ratio analysis and predictive machine learning is implemented to refine fiber laser drilling on Aluminium 6063. Complex relationships between process inputs—laser power, scanning speed, and pulse frequency—and critical quality metrics are evaluated. Through main effects plots, a significant positive correlation is identified between laser power and both Material Removal Rate and Heat Affected Zone width. Conversely, scanning speed is found to negatively impact these responses while improving circularity. By validating Multiple Linear Regression models, a robust process surrogate is established. Consequently, trial-and-error is minimized, allowing for adaptive, model-based design.

**Conclusion:** An integrated method combining the Taguchi approach and machine learning is verified to optimize laser drilling for Aluminium 6063. The most profound impacts on material removal rate and quality are found to be exerted by laser power and scanning speed. Optimal parameters for productivity and quality are identified, revealing a pivotal trade-off. Furthermore, multiple linear regression models are successfully developed and validated as credible predictive instruments to reduce industrial trial-and-error.

**Keywords:** Laser drilling, Machine Learning, Taguchi method, Aluminium 6063, Multi-objective Optimization

# Development and analysis of composite brick for energy efficiency, earthquake resistance, and waterproofing

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**Introduction** A composite brick designed to be waterproof, earthquake-resistant, and energy-efficient combines advanced materials like fiber-reinforced concrete, hydrophobic additives, and lightweight insulating cores. The outer layer prevents water penetration, while internal fibers and flexible materials improve seismic performance. An insulated core such as EPS or aerated concrete enhances thermal resistance. This multi-layer structure reduces structural load and improves indoor energy efficiency.

**Materials and Method:** Cement, fly ash, fine aggregate, lightweight aggregate (expanded clay/perlite), polypropylene or basalt fibers, hydrophobic additive (silane/siloxane), polymer modifier, and EPS/foam core material were used to develop the composite brick. Dry materials were uniformly mixed, followed by the addition of water and polymer admixture to form a homogeneous composite. Fibers and hydrophobic agents were incorporated during mixing. The mixture was cast in layered molds with an insulating core at the center and compacted properly. Specimens were cured for 7–28 days and tested for compressive strength, water absorption, and thermal conductivity.

**Result and Discussion:** The computational investigation under strong seismic vibration demonstrated that the proposed composite brick significantly outperforms conventional concrete and clay bricks in terms of structural stability and deformation control. Heterogeneous modeling of the composite structure revealed a more uniform stress distribution and reduced stress concentration zones under dynamic earthquake loading. Time-history analysis indicated lower peak displacement and inter-story drift in models constructed with composite bricks compared to traditional brick masonry. The composite brick also exhibited improved energy absorption and damping characteristics due to the presence of fiber reinforcement and lightweight core materials. Crack propagation was found to be slower and less severe, indicating enhanced ductility and toughness. Furthermore, the overall structural response showed improved load-bearing capacity and resilience under cyclic loading conditions. These results confirm that composite bricks are a promising alternative material for infrastructure in high seismic regions, offering enhanced safety, durability, and performance under realistic earthquake loading scenarios..

**Keywords:** Composite brick; Seismic performance; Heterogeneous modeling; Dynamic analysis; Earthquake resistance.

# OP-135: Cost-Effective Autonomous Underwater Vehicle for Marine Structural Health Monitoring

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**Introduction:** India's agricultural and economic stability relies heavily on a vast network of over 5,000 dams, many of which are aging and increasingly susceptible to structural defects such as cracks and erosion. Ensuring the safety of these structures is critical; however, traditional manual inspections by divers are hazardous, time-consuming, and limited by poor underwater visibility. While Remotely Operated Vehicles (ROVs) have been employed to mitigate human risk, they are often tether-dependent and require complex support systems, limiting their flexibility. To address these challenges, this research presents the development of a cost-effective, lightweight Autonomous Underwater Vehicle (AUV) designed for marine structural health monitoring. By eliminating the constraints of umbilical cables and focusing on power efficiency, our system aims to provide an accessible, automated solution for the consistent detection of dam cracks and subsea infrastructure inspection.

**Methods and Material:** This study utilizes a custom-built, lightweight AUV equipped with an onboard Raspberry Pi processing unit. The core inspection framework relies on a deep learning pipeline, specifically a YOLO architecture, trained on a dataset of underwater dam cracks to ensure real-time defect recognition. The vehicle features a modular design equipped with a five-thruster propulsion system for agile underwater navigation. Design feasibility was established through SolidWorks modelling and optimized for hydrodynamic stability through Ansys Fluent simulations.

**Result and Discussion:** Computational analysis confirmed that the streamlined chassis significantly minimizes fluid resistance, translating to extended operational endurance compared to standard ROV frames. The propulsion system demonstrated robust depth-holding and stability, essential for capturing clear inspection footage. Furthermore, the integrated crack detection algorithm showed high reliability in identifying surface discontinuities, validating its potential for autonomous assessment. The study concludes that this lightweight AUV architecture offers a cost-effective alternative to expensive, tethered systems, successfully lowering the barrier to entry for frequent dam safety inspections in developing regions.

**Conclusion:** The developed AUV proves effective for underwater structural health monitoring, providing a safer alternative to manual diving. Its energy-efficient design and robust detection capabilities ensure reliable performance in complex environments. This technology is recommended for routine inspections of dams and ports, ensuring long-term structural integrity and operational safety.

**Keyword:** *Autonomous Underwater Vehicle (AUV), Dam Crack Detection, Structural Health Monitoring, Deep Learning*

# OP-136: EXPERIMENTAL ANALYSIS OF POWER CONSUMPTION AND TIME TAKEN FOR PLA AND ABS MATERIAL IN 3D-PRINTING

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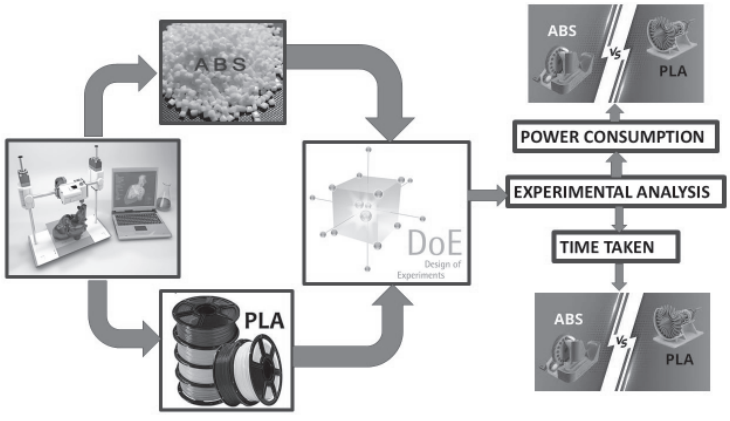
**Introduction:** The power consumption of a 3D printer depends largely on the thermal requirements of the material being processed. This study compares the energy usage of PLA (Polylactic Acid) and ABS (Acrylonitrile Butadiene Styrene) during fused deposition modelling (FDM) printing. PLA, with its lower melting temperature (180–210°C), requires less power for nozzle heating and generally does not demand a heated bed or operates at relatively low bed temperatures (40–60°C). In contrast, ABS requires significantly higher temperatures for both the nozzle (220–250°C) and the heated bed (80–110°C) to ensure proper layer adhesion and reduce warping, resulting in higher overall electrical energy consumption.

**Experimental Analysis:** Experimental observations consistently show that ABS prints consume 20–40% more power than PLA under similar print durations and geometries. The findings indicate that material selection has a substantial influence on the operational energy efficiency of FDM 3D printing, making PLA thermos energy-efficient option for low-temperature. The choice of material between PLA and ABS has a substantial impact on the energy footprint of a 3D print.

**Results:** ABS is the more power-intensive material, primarily due to the high and sustained energy required to maintain a hot print bed to prevent warping. PLA's ability to print at lower temperatures, particularly on a cooler or unheated bed, makes it a significantly more energy-efficient option. This analysis investigates the significant variance in electrical energy consumption when fabricating identical 3D models using PLA and ABS. Empirical data confirms that printing with ABS is substantially more energy-intensive, consuming 1.5 to 2 times more power per print job than PLA. The findings will provide empirical data for users and manufacturers to better understand the energy costs and environmental footprint associated with these common materials.

**Conclusion:** In the comparison between ABS and PLA material, PLA material uses less energy to print an identical geometric model and also take less time.




**Keyword:**3D-printing; PLA; ABS; Power consumption; Time taken

# OP-137: Comparative Life Cycle Assessment of Ethanol Production from Rice Grain and Rice Straw

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**Introduction:** Increasing usage of petrochemical energy for transportation has raised concerns related to degrading air quality and emission of greenhouse gases (GHG). Liquid biofuels a suitable alternative that requires environmental assessment to identify, predict, and mitigate the potential environmental, social, and health impacts of the production process and choice of feedstock. Life cycle assessment constitutes a pivotal analytical framework for quantifying the environmental impacts of bioethanol production, accommodating variations in feedstock and processing methods across diverse geographic regions and cultivation practices.

This study investigates the environmental impacts of bioethanol production via a life cycle assessment, comparing two different feedstocks i.e. rice straw and grain to assess their relative effects. Identifying environmental hotspots and resource-intensive processes for feedstock used enhances the clarity of this comparison and provides qualitative and quantitative data for improvement.

**Materials and Methods**: The comparative study adheres to the ISO 14040:2006 (principles and framework) and ISO 14044:2006 (requirements and guidelines). The system boundary is defined according to a cradle-to-gate approach, covering stages from feedstock cultivation to ethanol production and its delivery to the refinery gate. Foreground and background data if life cycle stages for conventional cultivation practice and standard refinery procedure were compiled to build the inventory. The functional unit was defined as 1 L of ethanol production from rice grain and rice straw, respectively, and used as a basis for comparison. Economic allocation was used to partition the environmental impact among products and co-products. Simapro 9 is used to develop the product system with the ReCiPe midpoint model and calculation of 18 impact categories.

**Results and Discussion:** The results show that the environmental profile of rice straw ethanol is significantly superior to that of rice grain ethanol across 17 of the 18 assessed impact categories. The Global Warming Potential (GWP) for straw-derived ethanol is 2.48 kg $CO_2$ eq/L, representing a 45% reduction compared to the grain pathway (4.52 kg $CO_2$ eq/L). In the grain pathway, the feedstock itself is the primary driver, accounting for roughly 70% of GWP (3.18 of 4.52 kg $CO_2$ eq) and over 99% of land use. Rice straw ethanol reduces water consumption by 85% (0.98 $m^3$ vs. 6.66 $m^3$ for grain) and land use by 70% (1.32 vs. 4.50 $m^2$a crop eq). The straw pathway shows a higher impact in stratospheric ozone depletion ($1.01 \times 10^{-5}$ kg CFC11 eq) compared to grain ($8.90 \times 10^{-6}$ kg CFC11 eq). Detailed analysis shows that Nitric Acid used in straw pretreatment contributes 84% of this specific impact. Grain ethanol relies heavily on external coal-based electricity, contributing 0.65 kg $CO_2$ eq to its total carbon footprint.

**Conclusion:** The LCA findings indicate that ethanol production from rice straw is more sustainable than from rice grain, primarily due to its lower carbon footprint, 85% reduced water use, and 70% less land use thus decoupling biofuel production from food competition. Although it shows slightly higher stratospheric ozone depletion due to nitric acid pretreatment, it outperforms rice grain ethanol in 17 out of 18 impact categories, making it ideal for a circular bioeconomy. Optimizing chemical recovery and renewable energy inputs will further minimize these trade-offs.

**Key words**: Biofuel feedstock; Bioethanol; Sustainability; Life Cycle Analysis; Alternate fuels

# OP-138: Free and Forced Vibration Characteristics of Multi-Fabric Bi-Directional Functionally Graded Composite Sandwich Plates

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**Introduction:** Hybrid fibre-reinforced polymeric sandwich composite plates are increasingly adopted in vibration-critical engineering structures due to their superior stiffness-to-weight ratio and tunable dynamic characteristics. Carbon fibre provides high stiffness and strength at higher cost, whereas E-glass fibre offers economic advantages with moderate mechanical performance. Recent studies indicate that hybridization using multi-fabric bi-directional weaving within a single fabric layer can significantly enhance both mechanical strength and modal response. However, most existing works focus on laminated plates rather than sandwich configurations with honeycomb cores. Furthermore, the influence of weave pattern–dependent stiffness on free and forced vibration behaviour of functionally graded sandwich composite plates remains insufficiently explored. This study bridges that gap by integrating multi-fabric woven hybrid face sheets with a lightweight honeycomb core to evaluate vibration performance under realistic boundary conditions.

**Methods and Materials:** Functionally graded reinforced polymeric sandwich plates are fabricated using the hand lay-up process. The face sheets consist of bi-directionally woven carbon and E-glass fibres arranged in graded and hybrid patterns inspired by C-X-C-Y, C-X-G-Y, C-Y-G-X, C-G-A, and G-X-G-Y configurations, embedded in an epoxy matrix (LY556 with MS91 hardener, 1:10 ratio). A hexagonal honeycomb core is manufactured using additive manufacturing with PLA/PET materials. Experimental modal testing is performed to obtain fundamental frequencies under C-F-F-F, C-F-C-F, C-C-C-F, and C-C-C-C boundary conditions. Finite element modelling is carried out using ANSYS 16.0 with SOLID185 elements and a refined 2 mm mesh. First-order shear deformation theory (FSDT) is used for face sheets, while higher-order shear deformation theory (HSDT/TSDT) is employed for the core to accurately capture transverse shear effects.

**Results and Discussion:** The vibration response is found to be highly dependent on fibre weave pattern and functional gradation. Plates with carbon-dominant weaving (C-X-C-Y) exhibit the highest stiffness and modal response, whereas glass-dominant patterns (G-X-G-Y) show the lowest. For instance, under C-F-F-F boundary conditions, experimental fundamental frequencies range from approximately 16.2 Hz (G-X-G-Y) to 27.6 Hz (C-X-C-Y), with corresponding finite element predictions of 18.5-31.2 Hz. Across all boundary conditions, experimental and numerical results deviate by less than 7-8%, confirming model reliability. The graded hybrid sandwich plates achieve vibration performance comparable to full carbon systems while reducing material cost significantly.

**Conclusion:** The integration of multi-fabric bi-directional weaving with functionally graded carbon–glass hybrid face sheets in sandwich composite plates results in enhanced vibration performance and cost efficiency. Carbon-dominant weave patterns maximize stiffness and natural frequencies, while hybrid configurations provide balanced dynamic response with reduced material usage. The combined experimental–numerical framework validates the effectiveness of the proposed sandwich design for vibration-sensitive structural applications.

**Keywords:** FGSP; carbon-glass fibre; core modal analysis; honeycomb

# OP-139: Fabrication and Mechanical Evaluation of ABS Polymer Composites Filled with PETG

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**Introduction:** Cracks frequently lead to premature structural failure due to damage such as small fracture initiation, delamination, fibre breaking, and part warpage in composite material structures. Identifying the crack detection in composite polymeric materials is crucial for safety and integrity of the structure. Since the composite materials are advanced heterogeneous materials, detecting damage within them is challenging due to their complex internal structure and varying material properties. The damage like cracks may be developed within internal layers or interfaces of composites, making them hard to identify using conventional inspection methods. The main aim of this research work is to fabricate hybrid Fiber Reinforced Polymer composites with two different synthetic fibers; and evaluating mechanical properties of these composites to check their suitability for structural application in aerospace, automobile and other engineering applications.

**Materials and Methods:** A composite sandwich beam is a lightweight structural element made of two strong outer layers (skins) bonded to a thick but lightweight core, designed to achieve high stiffness and strength with minimal weight. ABS is a three-monomer amorphous polymer made up of acrylonitrile, butadiene, styrene, and an opaque and oil-based thermoplastic.

A solid modeling is first prepared, and then ABS 3D printing specimens are obtained by fused deposition modeling (FDM) with Honeycomb Structure (162 mm X 62 mm) for different thickness. Then PETG is used as filler material to complete the structure. After fabrication of composites various mechanical property are performed on them to estimate their mechanical characteristics. Energy method for vibration analysis is used to find the mode shapes of the beam with different end conditions.

**Result and Discussion:** Fabricated the hybrid composite filled with PETG, All the mechanical properties are evaluated by doing different material testing methods. Theoretical natural frequency and mode shapes are found by different end conditions using Hamilton's principle.

The strength of our developed hybrid composite is better than all other composite material available in the market. The developed material also has good damping characteristics.

**Conclusion**: After fabrication of composites various mechanical property tests (Tensile test, Flexural test, Impact test and hardness test) are performed on them to estimate their mechanical characteristics. The test results of two composites are compared. From the comparison in tensile test results of two composites, it is found that the fabricate composite ABS-PETG has higher tensile stress and tensile strain than other composite material. Higher tensile strain of the PETG filled hybrid ABS composite indicates that the composite material deforms more before fracture. So, the composite is more ductile.

**Keywords:** 3D Printing, fused deposition modeling, mechanical properties, Acrylonitrile Butadiene Styrene, PETG, Hamilton's principle, ANSYS

# PP-140: AI-Driven Framework for Emission Estimation in Urban Scrap Recycling

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**Introduction:** Urban recycling systems play a measurable role in reducing greenhouse gas emissions by displacing energy intensive virgin material production. Despite this environmental benefit, scrap handling in many developing urban regions remains decentralized and largely undocumented. Due to lack of a standarized classification system it precludes the translation of recycling interventions into objective environmental key performance indictaors (KPIs). Existing waste management platforms focus primarily on logistics and collection efficiency, with limited attention to emission quantification at the source level. This work addresses the gap by proposing a computational framework that converts decentralized scrap flows into measurable environmental indicators using intelligent classification and model-based emission estimation.

**Materials and Methods:** The proposed framework consists of a three-layer computational pipeline: material classification, emission mapping, and aggregated impact modeling. Scrap streams are categorized into recyclable classes (metals, plastics, and mixed materials) using AI-assisted image classification logic based on supervised pattern recognition. Each class is mapped to standardized emission reduction coefficients derived from life-cycle assessment databases. A deterministic estimation function computes avoided CO2 emissions by comparing recycled processing energy with virgin production baselines. Aggregation is performed using weighted summation across categorized streams to estimate localized environmental impact. The system architecture supports hierarchical scaling, enabling

environmental datasets, ensuring reproducibility without physical instrumentation.

**Results and Discussion:** Analytical modeling shows that structured scrap classification enables consistent estimation of localized emission reduction. Aggregated recycling flows function as distributed environmental indicators capable of supporting urban sustainability monitoring. Even partial digital traceability produces actionable environmental

the feasibility of converting decentralized material recovery into computational sustainability signals.

**Conclusion:** The proposed framework establishes a scalable method for translating urban scrap recycling into measurable environmental impact metrics. By integrating AI-assisted classification with emission estimation models,

for intelligent environmental computing systems.

***Sustainable Computing***

# PP-141: An investigation of the socio-economic and environmental aspects of solar thermal energy–based multigeneration systems for coastal regions

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**Introduction:** Coastal regions face increasing challenges related to energy security, freshwater scarcity, climate vulnerability, and sustainable development. Solar thermal energy–based multigeneration systems integrated with agro-waste technologies such as anaerobic digestion and pyrolysis offer a sustainable solution by simultaneously producing electricity, heat, cooling, and potable water from renewable resources. This study evaluates the socio-economic and environmental performance of such systems in coastal regions, focusing on resource efficiency, greenhouse gas emissions, land and water use, and ecosystem compatibility.

**Materials and Method:** The study investigates a solar thermal–driven multigeneration system tailored for coastal regions. It integrates parabolic trough solar collectors, thermal energy storage, power production, desalination, and cooling units. A detailed thermodynamic model is formulated using mass, energy, entropy, and exergy balance equations. System performance is assessed through a comprehensive 4E analysis covering energy, exergy, exergoeconomic, and exergo-environmental aspects. Major components include Rankine cycle–based turbogenerators, steam generators, reverse osmosis and membrane distillation units, and a vapor absorption cooling system with chillers and heat pumps.

**Results and Discussion:** Unlike conventional solar thermal generation, Solar thermal multigeneration systems demonstrate varying energy efficiencies depending on configuration. It will be achieved 55% energy efficiency and 18% exergy efficiency for a coastal community system with an electricity, cooling, and desalinated water. Key economic indicators assessed include the levelized cost of energy (LCOE), levelized cost of water (LCOW), payback period, and net present value (NPV). The multigeneration configuration demonstrates improved cost effectiveness compared to single-output systems due to shared infrastructure and enhanced utilization of solar thermal input. Revenue diversification through simultaneous production of electricity, cooling, and freshwater contributes to reduced unit costs and improved financial resilience.

**Conclusion:** Solar thermal multigeneration offers a sustainable coastal solution, providing integrated energy services with environmental and social benefits through supportive policies.

**Keyword:** Multigeneration, Anaerobic, Incineration, Socioeconomic, Exergy, STG, VAS, LCOE, LCOW, NPV

# PP-142: Optimized Link Design for Space Parallel Robot with Bricard Mechanism

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**Introduction:** The space parallel robot with Bricard mechanism (SPRBM) is a promising solution for capturing free-floating space debris by enclosing objects with a deformable polyhedral container, without focusing on precise grappling locations. Although substantial studies have been carried out on its nonlinear kinematics, workspace, and trajectory planning, its link structure has been assumed instead of being optimized. However, the rods of the 3 RRS parallel mechanism and Bricard linkage should be sufficiently lightweight for launch while maintaining acceptable stiffness and strength for impact and repeated capture operations. This article extends the original study on the SPRBM by examining various geometries to achieve an optimal balance between mass, strength, and stiffness without sacrificing its kinematic characteristics.

**Methods and Materials:** Based on the geometric parameters and various modes of capture established by Liu et al., the architecture of the SPRBM is retained while various alterations are made to its links' cross-section, thickness, and sometimes length, while still maintaining acceptable kinematic constraints. Each link, which may be either a solid or hollow section with either a square or circular cross-section, is simulated to be made from aluminum alloy and is analyzed via finite element analysis under a variety of static structural analysis conditions. For each case, von Mises stress, tip deflection, and mass are calculated, from which various parameters such as stiffness to mass ratio and safety factor to unit mass are determined and arranged in a design matrix to better understand the trade-offs between competing requirements.

**Result and Discussion:** The results show that a range of hollow section designs can be found to significantly reduce mass relative to the baseline solid links, maintaining stresses at levels significantly below the yield stress and deflection levels small relative to the kinematically defined capture envelope. Two different trends are apparent for the square and circular tube designs. The former tend to show smoother stress trends, with the latter is capable of higher bending stiffness for the same mass when appropriately aligned relative to the primary load direction. A small number of Pareto optimal designs for the links are found to maintain the allowable workspace and capture diameter defined for the original SPRBM, while at the same time improving the stiffness to weight ratios and safety factors.

**Conclusion:** In the present study, the structural analysis and optimization of the design of the mechanical links of the SPRBM are combined with the established kinematic design. This provides a direct link between the theoretical design of the mechanism and simulation-based approaches suitable for space-based implementation. The study demonstrates the potential for improving the performance of the robot through relatively minor design changes to the cross-section of the mechanical links. This provides a foundation for the development of more efficient space-based robots for debris removal in future space missions.

**Keywords:** ***Space parallel robot, Bricard mechanism, space debris capture, link optimization, structural analysis***

# PP-143: Design and Development of Effective Four Bar Polycentric Knee Joint for Fully Furnished Above Knee Prosthesis.

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**Introduction**: According to World Health Organization census, Amputees produced in one year in India grouped by sex and geographical location around 25,000. 47 % of low- and middle-incomeamputees are unable to acquire an aid / prosthesis due to an unaffordable cost.The proposed conceptual design and research work aims to design and fabricate an effective Polycentric Knee joint within a nominal prescribed cost with more life period than the existing one, which is affordable by all Divyangjan amputees below poverty line. Conventional four bar knee and solid ankle joints have been commonly used in developing countries and Multi National companies in the field of Prosthetics and Orthotics. Currently the joints available in market are either high cost or the durability. However, they cannot achieve to design and development of a cost effective and highly durable knee joint, aiming to make it affordable and accessible for Divyangjan individuals below the poverty line.

**Materials and Methods**: Aluminium alloy, wrought 6082, T6 and Titanium are the materials to be used for the joint. Polycentric knee is an improvement type of prosthetic knee joint. Four bar mechanism was adopted in this type of prosthetic knee. It consists of four bars assembled in a closed loop. At any instant in time, a four bar polycentric knee is rotating around a particular point, called the Instantaneous Center of Rotation (ICR). It is an advantage that the four bar mechanism can be designed to better position the ICR point in the stability zone. The new four bar polycentric knee design has the potential to increase the stability limits of conventional four bar mechanisms during the stance phase, providing greater versatility and potentially improving stability while walking. 3D Printing, Differential Kinematics (vector Loop Method), Freudenstein Formulation and Grashof's Criterion are the methods used for the joint.

**Result and Discussion:** The 4 bar mechanism under analysis is a planar closed kinematic chain comprising four rigid bodies connected by revolute pairs. It satisfies the Grashof's and Grublerkutzbach Criteria for mobility. Using. Freudenstein formulation all the link lengths are found out for a proper motion of the knee. Accelerations and velocity of each length are found so that the mechanism will have a desired motion. It will be helpful in future for the researchers those are working on it, and they will also optimize to another next level. It will be a huge achievement for the Medical / Para Medical / Allied Health Care sector in future. Researchers will get more existing data to improve the design for their research field.

**Conclusion**: After reviewing a good number of journal papers, it is evident that existing knee joint designs either have limited durability or are prohibitively expensive. This research focuses on the design and development of a cost effective and highly durable knee joint that complies with government norms, aiming to make it affordable and accessible for individuals below the poverty line.

**Keywords:** Aluminum alloy, wrought 6082, T6Titanium, 3D Printing, Differential Kinematics (vector Loop Method), Freudenstein Formulation and Grashof's Criterion.

# OP-144: AHINSA - THE PEACE SILK FOR LORD JAGANNATH

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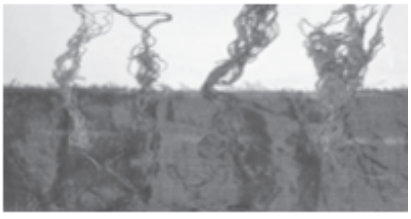
**Introduction:-** Silk is a highly valued natural protein fibre, known as the "queen of the fibres" for its luster, softness, and skin compatibility. The global silk industry generates substantial waste annually close to 11 million tons, necessitating high-value utilization through recycling and reuse—the core pillars of the circular economy. Beyond traditional textiles, silk excels in biomedical tissue engineering, filtration, and technical textiles due to its biocompatibility. From literature survey, it is obvious that the major challenge of mainstream application of waste recycling is dominantly luster and appearance, followed by mechanical properties degradation. Typically, for 300g Bombyx mori silk saree production, we kill: ~1,650–3,300 silkworms (low end) to ~6,600–16,500 (high end), per varying yields. Like the waste silk, the Ahinsa (peace silk –no killing of silkworm), the Eri silk from waste cocoons often suffers from poor luster and appearance, reducing its value for mainstream. The problem statement nerved us to investigate an eco-friendly processing route that will be of low cost, eco-friendly, and easy to use for handloom artisans. We extracted enzyme from papaya in our lab, made an experimental plan to optimize and compare with conventional methods, and established the scientific process that clearly ensures matching of the samples of Lord Jagannath's dress used conventionally to the treated Ahinsa silk yarn provided and requested by the Director of Textiles (Odisha). With available resources.

**Materials & Methods:-** Ahinsa silk yarn and the targeted silk fabric used by Lord Jagannath, provided by the Director of Textiles (Odisha) to match. ; 80/2 counts -KV Silk, Bangalore. The extracted enzyme solution was prepared by crushing dried fruit skin of Papaya with phosphate buffer, centrifuging, and filtering. $Na_2CO_3$– Lab Chemical, Acid dye –Red 3GL- Colour Tex, Silvassa. A Box-Behnken experimental design was followed, varying extracted papain volume (5, 10, 15 ml), $Na_2CO_3$concentration (0, 0.25%, 0.5% And temperature (35, 60, 85 $^0$ C). The reflectance reading, CIE L*a*b*and whiteness Index were measured in Visible Dual beam spectrophotometer (Model: 5100A, Make: Premium Colourscan)

**Results & Discussions:-** The best whiteness index **(WI-72.45)** was obtained using 15ml papain, no sodium carbonate ($Na_2CO_3$) at room temperature (35°C)and found to be optimum, which significantly exceeds the conventional treatment, as concluded by ANOVA Statistical analysis. The effect of Na2CO3 (5Ø]Ü-value 0.004) was more significant than the enzyme (5Ø]Ü-value 0.015) in affecting weight loss in a negative direction. The final regression equation for WI had an R-Squared value of 0.908. The best 4 lustrous yarns were dyed further and matched (figure below).



**Conclusion:-** This simple method of papain enzyme extraction and application significantly enhances luster with minimum weight loss for Eri silk, typically promoted now with ethics. It may convince the devotees, the handloom weavers of Odisha, to please the Almighty, being quite promising in terms of easy practice and economical, using peace-Eri or waste silk materials. Optimal conditions were identified to further investigate realising the potential of waste silk for high-value applications, providing a viable and sustainable strategy.

**Keywords:** *Silk waste, Papain enzyme, Degumming, Ahinsa silk, Whiteness Index, CIE L*a*b**

# OP-145: Evaluation of surface treatments on mechanical properties of plain woven jute fabric based biocomposite

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**Introduction:** A composite material combines two or more materials with different physical and chemical properties. These have specific properties including being stronger, lighter in weight and more durable. The researchers are focusing on bio-based composites and eco-friendly materials due to their lower environmental impact such as less carbon emission and fossil fuel consumption, biodegradability, lower cost, lower density, and ease of fabrication. This research aims to contribute to sustainable development of composite materials by investigating the potential of green composites by enhancing their performance by incorporating graphene.

**Materials and Methods:** Jute fibre and fabric have been procured from ICAR-Kolkata, India. Polylactic acid (PLA) granules from Deltora Biopolymers Pvt. Ltd., Gujarat. Graphene Oxide (GO) & reduced Graphene Oxide (rGO) from Techinstro, Nagpur. Alkali and silane were procured locally. Alkali treatment on jute fabric using sodium hydroxide solution typically of 5% & 10% concentration (w/l). Prepared a silane solution of 2% (w/w) silane agent (3-aminopropyltriethoxysilane) with 95% methanol and 5% distilled water. Dispersed GO & rGO with distilled water using different concentration % (w/w) solutions were observed using an optical microscope.

**Result and Discussion:** Alkali treatment on jute fabric using NaOH removes these impurities, exposing the cellulose content of the fibers. It was observed the water absorbency was higher at a 10% concentration than at 5%, improving surface roughness and promoting better mechanical adhesion with the matrix. After applying 2% (w/w) silane treatment to both the untreated and alkali-treated jute fabrics, we found that the water absorbency percentage was low in the untreated fabric and extremely low in the treated fabric. The dispersion level of GO and rGO with distilled water with different concentration % such as GO (0.5%, 1%, 1.5%, and 2%) and rGO (0.25%, 0.5%, 1%, 1.5%, and 2%) was observed with an optical microscope and the images were collected. Then the untreated jute fabric was immersed with GO and rGO solution for 1 & 0.5 hours. The water absorbency % was observed and was found that the absorbency was higher in GO and lower in rGO.

**Conclusion/Recommendation:** Graphene-treated natural fibers and biopolymer composites hold immense potential for revolutionizing the field of technical textiles. Jute fabrics were treated with alkali with different concentration%. Absorbency of alkali treated jute fabrics were investigated by the water drop test method and the absorbency % was observed. It was found the jute fabrics treated with 10% concentration of alkali showed higher absorbency level. Jute fabrics treated with 2% silane concentration showed very low water absorbency %. When the fabric were treated with different concentrations of GO and rGO, it was observed that the absorbency % was high in GO and low in rGO.

**Key Words: Alkali, *Bio-composite, GO & rGO, Jute fibre, Polylactic acid, Silane*.**

# OP-146: Surface Modification of Coir for Enhancement of Properties Related to Geotextile Applications

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**Introduction:** Coir, a lignocellulosic fibre extracted from coconut husk, is naturally biodegradable, renewable, and eco-friendly. However, its raw form exhibits limitations such as low mechanical strength, high moisture absorption, and poor resistance to microbial degradation. These drawbacks limit its effectiveness in long-term geotechnical uses. To overcome these issues, a chemical surface modification technique 'grafting' with Acrylic Acid (AA) was employed to improve the tensile strength of coir.

**Materials and Methods**: The grafting process involved chemically bonding AA onto the coir fibre using a solution containing potassium persulfate as an initiator and ferrous ammonium sulphate as a catalyst. The modified coir samples were evaluated for improvements in tensile strength and biodegradability. A soil burial test was conducted following ASTM D 5988 standards, simulating real environmental conditions to examine the degradation behavior of untreated and grafted coir samples over a 21-day period. The tensile strength was measured using the ASTM D 5035 standard to assess how the mechanical properties changed due to grafting and environmental exposure.

**Results and Discussion:** The results showed enhanced durability and resistance to microbial degradation. The tensile strength of AA grafted-coir increased from 1.00 MPa in untreated samples to 1.44 MPa post-grafting. Even after 21 days of soil burial, the grafted coir maintained a tensile strength of 1.24 MPa.

**Conclusion/Recommendation:** The study confirms that AA grafting significantly enhances the structural integrity and lifespan of coir fibres, making them viable for geotextile applications like prefabricated vertical drains. The study not only highlights the effectiveness of AA grafting in improving the performance of coir fibres but also supports the broader goal of promoting sustainable, biodegradable alternatives to synthetic geotextiles.

**Key words**: Coir, AA grafting, Geotextiles, Tensile strength, Soil Burial.

# PP-147: Biogenic synthesized $CaCO_3$ nanoparticles: Assessing dye degradation potential, phytotoxicity and antibacterial textile application

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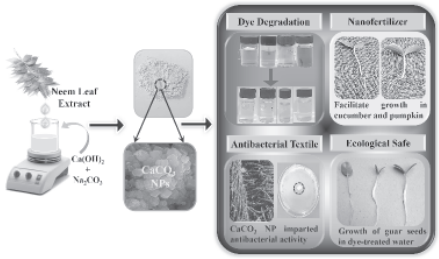
**Introduction:** The textile industry has seen an unprecedented boom in recent years and the textile industries are heavily dependent on dyes, which subsequently pave the path for the generation of wastewater effluent. The textile dyes are highly stable, aqueous soluble, and non-biodegradable. The ingestion or inhalation of these dyes has triggered respiratory/ skin infections, eye irritations and other maladies. In current times, an economical, ecologically safe, antimicrobial and reusable catalyst for environmental remediation is warranted. The utilization of green synthesized nanoparticles (NPs) has drawn attention as it is environmentally benign. The investigation of calcium carbonate NPs as photocatalysts for dye degradation is an interesting topic.

**Materials and Methods:** Fresh neem leaves were plucked from trees in OUTR campus, Bhubaneswar, Odisha. $Ca(OH)_2$ solution was added drop-wise to $Na_2CO_3$ solution. Neem extract was added to the aforesaid solution mixture and stirred at 60 °C for 3 h. The precipitate was oven-dried at 80 °C, which yielded the $CaCO_3$ NPs. Different analytical techniques such as UV-Vis, FTIR, XRD and FESEM were performed. Dye degradation studies and antibacterial analyses were carried out.

**Results and Discussion:** Green synthesis of the NPs was accomplished from *A. indica* leaf extract. The formation of $CaCO_3$ NPs was affirmed from UV–Vis spectroscopy by detecting the characteristic ëmax, a broad absorption band was noted in the range of 250–400 nm, which confirmed the synthesis of NPs. The XRD profile and FESEM image of the $CaCO_3$ NPs revealed the calcite phase of $CaCO_3$ polymorph with an average particle size of 75.25 nm. A band gap of 2.99 eV was estimated for the NPs from the Tauc plot. Photocatalytic efficacy of $CaCO_3$ NPs was investigated for methyl orange, crystal violet and methylene blue and their ternary mixture under sunlight. The NPs showed excellent photocatalytic efficiency in terms of dye degradation percentage and stability till the fourth cycle. $CaCO_3$ NPs-coated cotton fabric showed good antibacterial activity against *E. faecalis*. $CaCO_3$ NPs displayed good efficacy as a nanofertilizer for cucumber and pumpkin seeds.

**Conclusion:** Green synthesis of $CaCO_3$ NPs was accomplished via Neem leaf extract. The obtained CaCO3 NPs were characterized by different analytical techniques. A band gap energy of 2.99 eV was estimated using the Tauc method. The NPS depicted good photocatalytic dye degradation efficiency for hazardous textile dyes. The $CaCO_3$ NPs-coated cotton fabric displayed remarkable antibacterial efficacy against a common pathogenic bacterial strain, *E. faecalis*. Furthermore, the ecotoxicological assay indicated no inhibitory phytotoxicity on guar seedlings.

**Keywords:** Nano $CaCO_3$, Green s[illegible]otoxicity, Antibacterial textiles



# PP- 148: Energy-efficient low-salt reactive dyeing of cotton using gahnite nanoparticles synthesized from fly ash

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**Introduction:** Reactive dyeing of cotton is widely used due to its bright shades and excellent wet fastness. However, conventional processes require high salt, alkali, and temperature, resulting in high energy consumption and saline effluent generation. Sustainable textile processing demands reduction in chemicals and energy use. Recent studies show nanomaterials can enhance dye–fiber interactions. This study develops an eco-friendly, energy-efficient low-salt reactive dyeing method using gahnite nanoparticles synthesized from fly ash.

**Materials and Methods:** Scoured and bleached 100% cotton fabric was dyed with a vinyl sulphone reactive dye. Gahnite (ZnAl, O,, ) nanoparticles from fly ash were added to the dye bath at low concentrations. Conventional dyeing at 75 °C with standard Glauber's salt and sodium carbonate served as control. Experimental dyeing was conducted at room temperature with ~50% reduced salt and alkali in the presence of nanoparticles. Dyed samples were evaluated for color strength (K/S), CIELAB values, color difference (ÄE), tensile strength, bending length, elongation, and wash and light fastness.

**Results and Discussion:** Gahnite nanoparticles enabled effective dyeing at room temperature with reduced chemicals. An optimized recipe of 30 g/L salt, 7.5 g/L sodium carbonate, and 0.5 ml nanoparticles produced ÄE H" 0.9 compared to conventional dyeing, indicating good shade matching. K/S values were comparable to the 75 °C process. Wash fastness (3–4) and light fastness (4–5) met standard performance. Tensile strength improved by ~30%, while elongation and bending length showed minimal change. Improved dyeing is attributed to enhanced dye–fiber interaction due to nanoparticles.

**Conclusion:** Gahnite nanoparticles from fly ash enable low-salt reactive dyeing of cotton at room temperature, reducing chemical and energy use while maintaining color strength, fastness, and improving fabric strength. This approach offers a sustainable, industrially viable dyeing method and promotes utilization of industrial waste. Further work should focus on scale-up and environmental assessment.

**Keywords:** Reactive dyeing; Low-salt dyeing; Energy-efficient processing; Gahnite nanoparticles; Sustainable textiles

# PP-149: Design and Spectroscopic Evaluation of Disulfide-Based Chemosensors for Heavy Metal Monitoring

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**Introduction:** One of the biggest threats to the environment and public health is the growing contamination of soil and water by toxic heavy metal ions such as $Pb^{2+}$ and $Hg^{2+}$. Fluorescence-based chemo-sensors are efficient analytical tools because of their high sensitivity, fast reaction time, and simplicity of use. In this regard, the structural flexibility and affinity of disulfide-based organic probes for soft metal ions make them particularly advantageous. Two disulphide-based organic probes, bis(pentafluorophenyl) disulfide (PFTP) and Bis[2-(2-hydroxybenzylideneamino)phenyl]disulfide ,have been designed in this context and examined using a variety of analytical methods, including IR, NMR, SCXRD, UV-Vis and Fluorescence spectrometry). Furthermore, the synthesized disulphides were tested for colorimetric and fluorometric detection of $Pb^{2+}$ and $Hg^{2+}$ in the presence of different metal ions in a semi-aqueous solution. The sensors were discovered to have low detection limit values and a high binding constant (Ka). We believe that the present research offers a simple and effective method for creating organic sensors and encourages their use in bioanalysis, materials science, and environmental science.

**Methods and Materials:** A mixture of Thiols derivatives (1 mmol) and $H_2O_2$ (0.5 mmol) was stirred at 40 ÚC in EtOH (5 mL). The reactions were monitored using TLC. After completion of the reaction, the volatile compound was removed under reduced pressure. The disulfide products were isolated in 93–97% yield.

**Result and Discussion:** PFTP, the absorption peak at 265 nm shifts upon interaction with ions like $Hg^2$, $Pb^{2+}$ and, while its fluorescence profile shows a significant "turn-on" response at 400 nm and 530 nm primarily. Similarly, the DIS displays a primary absorption at 335 nm that shifts significantly with, but its most striking feature is the dramatic fluorescence enhancement at 540 nm, specifically in the presence of $Hg^{2+.}$ When integrated with IR and NMR data, these results suggest that the coordination of metal ions to the imine nitrogen and phenolic oxygen atoms (in DIS) or the disulfide linkage (in PFTP) restricts internal molecular rotation and suppresses photoinduced electron transfer (PET). This structural rigidification transitions the probes from a "dark" non-fluorescent state to a "bright" emissive state, providing a clear optical signal for the detection of toxic metals like $Pb^{2+}$ and $Hg^{2+}$.

**Conclusion:** Disulphide-based organic chemo-sensor has successfully synthesized and characterized by various analytical techniques. The colorimetric and fluorometric detection of various metal ions was performed in a semi-aqueous solution. The limitation in internal charge transfer caused both sensors' "turn-on" fluorescence response to these ions. According to Job's plot and semi-empirical calculations, PFPT and DIS complexed with $Pb^{2+}$ ions in a 2:1 ratio and $Hg^{2+}$ ions in a 1:1 ratio, respectively. The current finding suggests that the disulphide-based candidate can be used in hazardous metal pollutant detection and environmental monitoring.

**Keyword:** ***Chemo-sensor, Detection, Heavy metal ions, Organic sensor, Disulphide***

# PP-150: Advanced DT-TI Controller for Load Frequency Regulation in Renewable Integrated Egyptian Grids

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**Introduction:** One of the main causes of power outages in electrical power networks is frequency instability. Establishing a feasible grid that provides users with steady power is the primary goal of a power system. The demand for electricity is rapidly increasing due to the needs of industrial sectors. The scarcity of coal is decreasing day by day, which is insufficient in nature. One of the most intriguing and promising energy areas for fossil fuels is renewable energy. The major sources of renewable power are from wind and solar power which is intermittent in nature. When solar and wind power are connected to the grid, their randomness causes frequency oscillations and reduces the stability of the power supply. The micro grid's primary role models are solar and wind energy, whose frequency must be stabilized. Appropriate control strategies have been devised to reduce frequency oscillation and stabilize the frequency.

**Methods and Material:** A centralized and decentralized Egyptian power grid (EPG) has been introduced by derivative filter with tilt integral (DF-TI) controllers. A new hybrid technique known as the harmony search algorithm with bandwidth reduction (HSA-BR) mechanism has been applied to optimally allocate gains of DF-TI controller. Non-reheat, reheat and hydraulic power systems as well as intermittent power systems (wind and solar) has been used to test the efficacy of suggested controller. Non-linearities such as generation rate constant, rate limiter, governor dead band are also taken into consideration.

**Result and Discussion**: The performance of DF-TI controller has been tested on different parameters such as communication time delay (CTD) and variation of inertia constant of generators. Various load patterns such as wind, ramp, staircase and pulse loads are applied to both decentralized and centralized power grid. The simulation results are in line with decentralized grid which offers more stabilization than centralized grid in terms of peak deviation and calming latency. By comparing with other optimization methods, the standard deviation of DF-TI is 1.5167e-04 with mean error of total 0.0009. The integral square error is about 160% and settling time is enhance by 68%.

**Conclusion:** The proposed decentralized and centralized models have been optimally controlled by DF-TI controller with HAS-BR algorithm. The performance of decentralized model of EPG is better under various loading conditions.

**Keyword:** ***EPG, DF-TI, CTD, HSA-BR***

# PP-151: Novel Fault Detection & Classification Index for Active Distribution Network Using Differential Components

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**Introduction:** The increasing integration of distributed generation resources (DGRs) in distribution systems has transformed conventional passive networks into active distribution networks (ADNs) consisting of microgrids and multi-microgrids. Although this integration improves reliability and power quality, it significantly alters fault current characteristics, bidirectional power flow, and network topology. Consequently, conventional protection schemes often fail to detect and classify faults accurately, particularly low impedance faults (LIFs) and high impedance faults (HIFs). Reliable fault detection and classification in ADNs therefore remain a critical challenge.

**Materials and Methods:** This work proposes a novel fault detection and classification technique for ADNs based on the energy associated with the differential superimposed positive sequence impedance. Positive sequence voltages and currents are measured at both ends of the protected feeder using intelligent electronic devices. The superimposed impedance is derived from pre-fault and fault conditions, and its differential component is processed using an energy operator. Based on this energy measure, a Fault Detection Index (FDI) and a Fault Classification Index (FCI) are formulated to identify and distinguish LIFs, HIFs, external faults, and non-fault events such as switching transients and nonlinear load conditions**.**

**Results and Discussion:** The proposed method is validated on a modified IEEE-13 bus distribution system integrated with single and multiple microgrids. Extensive simulation studies demonstrate accurate detection and classification of LIFs and HIFs under various operating scenarios, including internal and external faults, capacitor and load switching, nonlinear loads, measurement noise, and communication delays. The method shows high selectivity and robustness, avoiding mal-operation during non-fault events. Real-time validation using a control hardware-in-the-loop setup further confirms fast response and reliable performance suitable for practical deployment**.**

**Conclusion:** The proposed differential impedance energy-based protection scheme provides an effective and reliable solution for fault detection and classification in active distribution networks with microgrids and multi-microgrids. By accurately identifying LIFs and HIFs while discriminating against external faults and switching events, the method overcomes key limitations of conventional protection techniques. Simulation and experimental results confirm its robustness, speed, and applicability for real-time protection of modern distribution systems.

**Keywords**: Active Distribution Network, Fault Detection, Fault Classification, High Impedance Fault, Low Impedance Fault, Microgrids, Differential Protection

# PP-152: Manta Ray Foraging Optimization Based Virtual Inertia Controller for Frequency Stabilization of Islanded Micro-Grid

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**Introduction:** Manta Ray Foraging Optimization (MRFO) algorithm optimized Proportional-Integral (PI) controller is used for controlling of frequency of a standalone micro grid (MG). The MG system is made up of a Diesel Engine Generator (DEG), Fuel Cell (FC), Micro Turbine (MT) and photovoltaic (PV) systems with maximum power point trackers (MPPT). The virtual inertia control (VIC) is also used to provide the inertia during transient condition. Three PI controllers are used for controlling of MPPT, VIC and Diesel engine generator. The MRFO algorithm uses an Integral of Squared Error (ISE) objective function to optimize the gains of the PI controllers. The simulation is carried out with different case studies. When compared to the results of other optimization approaches for the same MG, such as Salp Search Algorithm, Particle Swarm Optimization, and Teaching Learning Based Optimization, the MRFO-based PI controller outperforms them in all scenarios. According to the simulation findings, the MRFO technique gives better dynamic responses like overshoot, undershoot value, settling time, and Integral squared Error. It is also observed that with presence of VIC, the performance of MG improved.

**Materials and Methods:** The MG system under consideration is comprised of DEG, FC, MT, PV with MPPT, FES, BESS and WT. The output of one PI controller is linked to DEG, FC and MT, similarly second PI controller output is linked to PV with MPPT to lessen the MG's frequency deviation and third PI controller is linked for controlling of VIC in order to achieve a faster steady-state response. The wind power is not used for the secondary because it is intermittent in nature. The objective function in this study is the integral of the squared error (ISE).

**Results and Discussion**: The proposed MRFO algorithm is employed to tune the controller gain considering ISE criteria as the objective function. The control parameters of MRFO consists of 20 manta rays and 100 iterations. The optimization process was repeated 20 times to obtain the best fitness. The performance of the MG with the proposed approach was investigated considering the various case studies.

**Conclusion:** The use of a PI controller based on Manta Ray Foraging Optimization (MRFO) for frequency regulation of a stand-alone micro grid (MG) is presented in this study. Five distinct case studies were taken into consideration when examining the MG's performance using the suggested method. findings from SSA, PSO, and TLBO-based PI controllers are compared with simulated findings from MRFO-based PI controllers. According to the comparison, the suggested method performs better than the other methods under different conditions in terms of lowering frequency deviation, settling time, peak overshoot, and undershoot.

**Key words**: Frequency regulation, microgrid, manta ray foraging optimizer, renewable energy.

# PP-153: Thermal Modeling Analysis of Passive Solar Photovoltaic Thermal System

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**Introduction:** In the Present era of energy moving toward renewable, solar energy is a primary focus for researchers and scientists because it is free, feasible, sustainable, less impact on climate change. Solar energy can be harvested using photovoltaic (PV) collectors or solar collectors. Photovoltaic (PV) cells lose power efficiency as a result of warming up in the sun. In this, detailed Thermal energy modeling is carried out on a photovoltaic thermal (PV/T) system considering the passive cooling method. PV/T systems are hybrid systems combining both methods to produce electrical energy & thermal energy to maximize solar energy collection and overall performance.

**Methods and Materials**: The flow of water below the PVT through copper tube to collect the heat from the solar panel and cool the solar panel, which will help to decrease the panel temperature. The thermal energy modeling analysis is done analytically by using Matlab to calculate energy and exergy, overall efficiencies of the system at varying mass flow rate and no of tubes around the year.

**Results and Discussion:** The thermal and electrical performance of a PVT system is obtained based on thermal energy modeling. The energy harnessed from the PV and PVT are obtained having 4 tubes and 8 tubes using water of the system, analyzing PV, PVT with 4 tubes, and PVT with 6 tubes 8 tubes in Bhubaneswar zone with different mass flow rate. The energy efficiency was found to be between 0.12 and 0.18 for both PV and PVT systems. The Panel temperature also has been reduced by varying no of tubes. However, considering thermal effectiveness, the system proves more effective .The year-round weather data corresponding to Bhubaneswar, a city in east-coastal zone of India are employed for data reduction. During January, February, December, and November, the water temperature increased by 4-7°C. The overall efficiency of PVT system has been improved.

**Conclusion:** The thermal efficiency ,exergy and overall efficiency is improving with varying no of tubes. PV/T systems effectively collect solar energy, increasing electrical power output and simultaneously collecting solar heat that can be used for industrial and household purposes.

**Key words**: Photovoltaic thermal, passive method, Overall efficiency, Energy modeling, Weather data

# PP-154: Effect of Blood Sample Storage on Red Blood Cell Morphology and Membrane Stability

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**Introduction:** Red blood cells (RBCs) are specialized, highly deformable cells that must repeatedly squeeze through the capillaries (blood vessels that are smaller than their resting diameter) to ensure effective oxygen transport in microcirculation. RBC deformability depends on its membrane structure, composition, elasticity, cytoskeletal organization, intracellular viscosity and osmotic stability. However, storage of blood samples has been known to affect the metabolic and mechanical function of erythrocytes both under physiological conditions and pathological conditions. For example, delays in blood sample collection, storage and processing can significantly compromise the measurement accuracy in laboratory and clinics. Although morphometric deformation analysis, measurement of biochemical markers such as ATP and hemoglobin release are widely used to assess membrane stability and cellular stress responses, effect of storage on these processes are poorly defined *in vitro*.

**Materials and Methods:** Peripheral venous blood samples were collected from healthy volunteers categorized into defined age groups (young, middle-aged, and elderly) and stored for different durations (8, 16, 24, 48, 72 Hours). Samples were collected in EDTA tubes to prevent coagulation. RBCs were isolated by centrifugation and washed with phosphate-buffered saline to remove plasma and buffy coatings. Mechanical deformation was induced by varying centrifugation speed and [NaCl] of the bath medium. For shear-based deformation, RBC suspensions were exposed to centrifugation, pipetting and vertexing. For osmotic stress exposer cells were subjected to hypotonic conditions and to evaluate membrane stability through Hb measurement, spectrophotometrically. Post-treatment, samples were immediately prepared for microscopic imaging. High-resolution microscopic images were captured under standardized magnification. Morphometric parameters including cell area, perimeter, circularity index and aspect ratio were quantified using image analysis software. To assess membrane damage and metabolic response, extracellular ATP levels were measured using a luminescence-based assays.

**Result and Discussion**: RBCs obtained from younger individuals demonstrated greater deformability under applied stress, compared to that of cells from younger subjects. These cells maintained structural integrity with minimal hemoglobin leakage and controlled ATP release, suggesting preserved membrane stability. In contrast, RBCs from elderly individuals showed reduced deformation and greater vulnerability to membrane disruption. Elevated hemoglobin release indicated increased fragility, while altered ATP signals suggested compromised mechanical stability under stress conditions.

**Conclusion**: This preliminary results demonstrate the significant differences in RBC morphology and deformation behavior across various storage intervals and age groups. While younger RBCs seems to exhibit superior mechanical flexibility and membrane stability, the older RBCs show reduced flexibility and are more susceptible to deformation-induced lysis. Combining morphometric analysis with ATP and hemoglobin measurements offers a unique platform to quantify the contribution of RBC deformation in ATP-mediated control of vascular tone in health and disease. Overall, the present pilot study emphasizes the importance of careful sample storage practices in maintaining the membrane integrity of red blood cells for accurate measurement of extracellular ATP or Hb under stress.

***Keyword**: Red Blood Cells, Deformability, Sample Storage, Morphometric Analysis, ATP Release, Hemoglobin.*

# PP-155: Effect of Temperature and Hematocrit on Nonlinear Blood Rheology: A Constitutive Model-based Analysis

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**Introduction:** The viscosity of blood is a measure of its resistance to deformation, and generally increases with the proportion of the blood composed of red blood cells (hematocrit) and reduced temperature. This relationship is exaggerated at low flow rates due to the non-Newtonian fluid properties of blood. Consequently, the viscosity of the blood is nonlinear and shear rate dependent, representing the rate of change of fluid velocity when one layer of fluid passes over an adjacent layer, and at low shear rate, the red blood cells tend to spread out more evenly within the vessels. Although relationship between blood viscosity and shear rate has been extensively studied experimentally, the factors affecting low shear-dependent changes in viscosity under steady and time-dependent flow and spatiotemporal variation in erythrocyte dynamics are incompletely understood.

**Materials and Methods:** This study aimed to address the problem of inferring various constitutive model parameters by fitting them to experimental data on blood viscosity, measured under diverse experimental conditions. By model fitting to published data, a set of parameters that are able to capture nonlinear behavior were identified. The fitted parameters yielded almost indistinguishable fits to experimental data, but the different parameter sets predicted very different viscosity profiles. The model-based analysis of viscometer data, measured over a wide range of shear rates and by varying temperature and levels of haematocrit gives a minimal constitutive model that can be used for blood flow modelling. Specifically, the best model was chosen based on RMSE values, goodness of fits and parameter sensitivity analysis.

**Result and Discussion**: Model analysis of blood viscosity data reveals that the blood displays high viscosity at low shear rates, which basically decreases as the shear rate increases (shear-thinning effect). Increased hematocrit dramatically elevates blood viscosity consistent with experiments. Furthermore, when blood behaves as a non-Newtonian fluid, viscosity increases approximately 2-4% for every degree Celsius fall in temperature. The constitutive model used here indicates, at 15°C blood viscosity is significantly higher than that at 37°C. A versatile model for blood must be continuous over a wide range of hematocrit, temperature and shear rates.

**Conclusion**: This empirical model-based analysis of blood viscosity demonstrates the effect of hematocrit and temperature on the relationships between apparent blood viscosity and shear rates. Constitutive modeling of blood rheology plays a crucial role in capturing broad spectrum of complexity, observed *in vivo*. The commonly used Newtonian model that uses an asymptotic viscosity shows good computational efficiency and suitable for representing viscosity under high shear stress. On the other hand, when the shear rate and hematocrit are spatially heterogeneous, a more sophisticated model is necessary.

***Keywords**: Blood Rheology, Constitutive Modeling, Non-Newtonian Fluid, Hematocrit, Model-based Analysis*

# PP-156: ESTIMATION OF SOIL EROSION AND SEDIMENT YIELD ON ONG CATCHMENT, ODISHA, INDIA

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**Abstract:** Soil erosion is one of the major environmental challenges in India, and its precise estimation over specific time periods is often difficult due to the complex interaction of rainfall, soil, topography, and land use. In recent years, several experimental and theoretical approaches have been developed to estimate soil erosion at watershed scale, with **Geographical Information System (GIS)** emerging as a vital tool for sediment yield assessment.In the present study, GIS-based methods were used to estimate the sediment yield of the **Ong River Basin, Odisha**, located in the lower **Mahanadi region**, covering an area of **5128 km²**. The Ong catchment was selected due to the availability of gauged hydrological and sediment data at multiple locations within the watershed.

**Methodology:** The study employed the **Universal Soil Loss Equation (USLE)** for estimating gross soil erosion. Originally developed for croplands on sloping terrains (Wischmeier and Smith, 1978), USLE and its later modifications—**MUSLE** and **RUSLE**—have been widely adopted worldwide for estimating soil loss under diverse land-cover conditions, including forests, rangelands, and disturbed areas (Renard et al., 1997). USLE assumes that soil detachment and deposition are governed by the sediment transport capacity of surface runoff. When flow reaches its maximum transport capacity, no further detachment occurs.

In this study, the Ong catchment was divided into homogeneous grid cells to capture spatial heterogeneity. For each grid cell, the USLE factors—**R** (rainfall erosivity), **K** (soil erodibility), **L** (slope length), **S** (slope steepness), **C** (cover management), and **P** (conservation practice)—were derived using spatial datasets processed in ArcGIS 10.2. Gross soil erosion for each pixel was computed using:

$A=R\times K\times L\times S\times C\times PA = R \times K \times L \times S \times C \times PA=R×K×L×S×C×P$

The computed pixel-wise gross erosion values were then routed along hydrological drainage paths to estimate transport-capacity-limited sediment delivery at the watershed outlet. The resulting sediment outflow maps indicate the rate of sediment leaving each grid cell and allow identification of erosion hotspots.

**Results and Discussion:** The highest theoretical sediment yield was found to be **21.93 tons/ha/year**. Summation of all grid values yielded a total annual sediment yield of **5510.30 tons/year**. Observed sediment yield, calculated from daily discharge and suspended sediment data obtained from **India-WRIS**, was **4629.29 tons/year**. The resulting estimation error was **19.02%**, indicating good agreement between modeled and observed values. The **Salebhata** gauging station recorded the highest sediment yield at **24.3 tons/ha/year**, highlighting it as a critical erosion-prone zone.

**Conclusion:** Water-induced soil erosion remains a significant concern in Odisha due to its climatic and physiographic characteristics. This study successfully integrated **ArcGIS 10.2** with the **USLE model** to map erosion intensity and spatial patterns of soil loss in the Ong catchment. The methodology effectively identified high-risk erosion zones and provided reliable estimates of sediment yield, demonstrating its usefulness for watershed management, soil conservation planning, and sustainable land-use strategies.

***Keywords:*** DEM, GIS,Soil Erosion Sediment yield, USLE, ONG catchment, lower Mahanadi region.

# PP-157: Agrochemical Biodegradation of Paddy Soil by Indigenous Microbial Consortia

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**Introduction**: Paddy fields (*Oryza sativa* L.) form the backbone of global rice production feeding over half the world's population especially in Asia, where India ranks as the second-largest producer. In Odisha, farmers apply 1–2 kg/ha of agrochemicals annually including organophosphate insecticides mostly chlorpyrifos, malathion and glyphosate that leads to soil contamination where they trap these chemicals by limiting their volatility and photodegradation that ultimately degrades the soil fertility and human health risks via biomagnification making bioremediation essential. Microbial consortia surpass single isolates in bioremediation by collectively withstanding environmental stresses such as pH, temperature, etc enabling faster and more efficient degradation unlike isolates that falter under such pressures. In consortia, byproducts from one strain serve as substrates for others yielding simplified end products with reduced metabolic stress, whereas single isolates struggle to fully mineralize complex pollutants alone. This study evaluates the degradation efficacy of these consortia against key agrochemicals by prioritizing prevalent organophosphates with molecular characterization of isolates and soil health assessments to devise practical bioremediation strategies while focusing on controlled setups rather than variable naturally contaminated coastal soils.

**Methods and Material:** Paddy soils with agrochemical exposure history were sampled (10–15 cm depth), air-dried overnight and analyzed for physicochemical properties such as pH, texture, Total carbon content, etc using standard protocols. Soil suspensions (1 g/9 mL) underwent 10-fold serial dilution from which 0.1 mL aliquots ($10^{-t}$ to $10^{-w}$) were spread-plated in triplicate on Nutrient Broth medium for yielding pure bacterial colonies after 24–48 h. Selected isolates were purified, enriched in fresh medium and screened for degradation efficiency against target agrochemicals. Promising strains formed consortia and were evaluated for broad-spectrum degradation. Molecular/biochemical characterization and degradation pathway analyses elucidated mechanisms and optimizing biodegradation strategies for sustainable paddy soil restoration.

**Result and Discussion:** Pot experiments are expected to demonstrate that the *Micrococcus aloeverae* (MAGK3) + *Bacillus cereus* (AGB3) + *Bacillus paramycoides* (AGM5) consortium fully degrades malathion (500 mg $kg^{-1}$) by day 15, outperforming isolates (80–100% vs. 40–60% efficiency). Consortia resilience to soil stresses (pH, moisture) and synergistic byproduct cross-utilization should surpass single strains thus validating indigenous microbes for multi-residue organophosphate bioremediation in paddy soils.

**Conclusion:** India ranks third in Asia and 12th globally in pesticide use with organophosphates contaminating paddy soils harming non-target organisms, disrupting food chains and posing human health risks via bioaccumulated residues in tea, fruits, vegetables, blood and milk. Thus, we can conclude that indigenous microbial consortia (e.g., *Pseudomonas* sp., *Bacillus cereus*, *Micrococcus aloeverae*) can outperform single isolates (80–100% vs. 40–60% efficiency) by withstanding environmental stresses collectively—unlike isolates which are vulnerable to stressors by enabling rapid degradation. This study successfully resolved prior limitations in consortium-based multi-residue biodegradation by establishing indigenous microbes as viable agents for mitigating persistent soil contaminants, enhancing fertility and advancing sustainable agroecosystems.

**Keyword:** ***Paddy field, Agrochemicals, Biodegradation, Organophosphates, Microbial Consortia***

# PP-158: Solvent extraction of zirconium(IV) from a nitric acid medium in kerosene utilizing several extractants: TOA, Cyanex 923, and binary mixtures

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**Introduction:** Zirconium is the second-row transition element with the symbol Zr, atomic number40, and atomic mass 91.224 a.m.u. It belongs to the titanium subgroup, subgroup IVB. Thename of zirconium is taken from the mineral zircon, the most important source ofzirconium, and from the Persian word "Zargun-, which means gold-like metal. Zirconiumis a grey, lustrous metal, hard and ductile, with the appearance of stainless steel availablein the form of platelets or flakes. In powder form, zirconium is highly flammable, but thesolid form is less prone to ignition, and the colour is bluish black. Zirconium is an elasticmetal, like other metals with lower melting points. Its mechanical strength decreases withincreasing temperature. Zirconium is very abundant, but is typically found in orescombined with other elements.

**Methods and Materials:** Zirconium oxychloride(AR grade, Merck, India) and TOA, Cyanex 923, Nitric acid(99%, Loba) were used for the experiment, with Millipore distilled water and kerosene as the solvents.The separation processes, such as solvent extraction,aregenerally usedfor removing zirconium (IV) from aqueous medium to organic medium in the presence of TOA, Cyanex 923 as extractant, and nitric acid medium.The distribution ratios have beencalculated using a UV-VIS spectrophotometer by the Arsenazo III method.

**Result and Discussion:** The effect of various parameters, such as acid concentration,extractant concentration, salting-out reagent concentration, temperature, metal ion concentration, and diluents on synergistic extraction of Zr(IV) has been studied.The optimum conditionsfor the extraction of Zr(IV) from the organic phase have been established. The percentage ofextraction becomes maximum when kerosene is used as a diluent. The extraction of Zr(IV)increases with an increase in acid concentration, extractant concentration, and metal ionconcentration. The percentage of extraction decreases with an increase in temperature, and theextraction process is exothermic, accompanying with an increase inrandomness. Both $HNO_3$ and $Na_2CO_3$are effective strippers for stripping themetal from the loaded organic phase. The study uses a liquid-liquid extraction method employingCyanex 923 and TOA in kerosene to investigate the behavior of zirconium (IV) extraction fromnitric acid. Changes in temperature, metal concentration, diluent effect, extractant, acidity, andother parameters were investigated.

**Conclusion:** The study explores solvent extraction processes for removing zirconium (IV) from aqueous to organic medium using TOA and Cyanex 923 in a nitric acid environment. Factors like acid and extractant concentrations, temperature, and diluents were analyzed, revealing maximum extraction efficiency with kerosene as the diluent and increasing acid, extractant, and metal ion concentrations. Conversely, increased temperature reduced extraction efficiency, indicating an exothermic process. Both $HNO_3$ and $Na_2CO_3$ effectively stripped zirconium from the organic phase. The research utilized UV-VIS spectrophotometry and the Arsenazo III method for distribution ratio calculations.

***Keywords: $ZrOCl_2$,TOA,Cyanex 923, Cyanex 921,Kerosene.***

# PP-159: Enhancing Interfacial Bonding in Bio-Fiber Roofing Sheets: A Physicochemical Investigation of Alkali-Treated Sabai Grass for GGBS-Filled Composites

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**Introduction:** Rural housing in Odisha has been exposed to cascading hazards such as heatwaves, cyclones, and floods, often occurring in quick succession. These compounding events highlight major performance limitations in **Pradhan Mantri Awas Yojana (PMAY)** settlements, where conventional roofing materials fail to ensure thermal comfort and moisture resistance. In line with the PMAY-U 2.0 Technology and Innovation Sub-Mission (TISM), this research proposes a cost-effective and sustainable eco-bio-composite roofing sheet. Using KOH-treated Sabai grass as reinforcement and GGBS as a low-carbon binder, the study aims to develop a durable roofing solution for climate-vulnerable regions.

**Methods and Materials:** This study used Sabai grass (*Eulaliopsis binata*), a locally available natural fiber from Odisha known for its high tensile strength. To reduce hydrophilicity and improve fiber–matrix interfacial bonding, the fibers were mercerized using 3%–9% KOH solutions. Ground Granulated Blast Furnace Slag (GGBS) was added as a filler to improve mechanical strength, chemical durability, fire resistance, enhance densification, and reduce production cost. Fiber density and tensile strength were measured for physical characterization. Chemical composition was determined using the Van Soest method, and fiber surface & interfacial morphology was analysed using Field Emission Scanning Electron Microscopy (FESEM).

**Results and Discussion:** The chemical analysis showed a strong link between alkali concentration and Sabai grass fiber composition. As KOH concentration increased, hemicellulose and lignin levels decreased significantly. A 5% KOH treatment was found to be the most effective for removing non-cellulosic components without harming the fiber structure. Physical tests confirmed that fiber density increased initially but started decreasing beyond 5%. The 5% treated fibers further showed the lowest water absorption 90.26%, and highest tensile strength 317.78 MPa. Therefore, 5% KOH-treated Sabai grass is the most suitable reinforcement for durable, weather-resistant roofing applications.

**Conclusion:** This study confirms the feasibility of an eco-bio-composite roofing system for disaster-prone PMAY communities in Odisha. Sabai grass treated with 5% KOH shows improved density and moisture resistance, with reduced hemicellulose and lignin content and enhanced fiber–matrix bonding. Using GGBS as a filler supports circular economy principles and offers a durable, low-cost alternative to conventional roofing.

**Keywords:** ***Sabai Grass (Eulaliopsis binata), GGBS (Slag), Mercerization, Bio-composites, Sustainable Construction, Circular Green Economy, Climate Resilience***

# PP-160: Parametric Investigation of Chord Spacing in Cold-Formed Steel Battened Columns under Axial Loading

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**Introduction:** This research work aims to analyze the axial behavior of cold-formed steel (CFS) battened columns using finite element analysis in ABAQUS 2020. The parametric analysis is carried out to assess the influence of chord spacing on buckling performance and load-carrying capacity. The batten spacing ranged from 0 mm to 40 mm, and the maximum strength of 32.5 kN was achieved at 40 mm spacing. The zero-spacing resulted in early local buckling and reduced peak load capacity. The research work also compares flat and hooped battens to identify various buckling modes and failure mechanisms. Geometric imperfections (10%) were also considered, and it is found that there is a 5% reduction in peak load capacity, resulting in more realistic and optimized column designs.

**Methods and Materials:** The structural components were modeled using S280GD+Z, a galvanized, cold-formed steel characterized by a high strength-to-weight ratio. A batten column is simulated using finite element analysis. The column length is 2200 mm, and the depth of a web and the flange width may be 100 mm and 30 mm correspondingly. This section has uniform wall thickness = 1.25 mm. To represent a rigid connection at the base, an encastre boundary condition was applied to the bottom of the column. The loading is applied at the top end via a displacement-controlled loading condition. Nonlinear static analysis is performed on 3 configurations of chords placement (0 mm, 20 mm and 40 mm). To accurately capture the structural response under load, geometric nonlinearity was considered in all simulations.

**Results and Discussion:** The nonlinear static analysis revealed that chord spacing significantly influences the axial performance of CFS battened columns. An increase in chord spacing improved both initial stiffness and overall load-carrying capacity. Force displacement results displayed a gradual increase in stiffness and capacity to bear load as the spacing among chords increased. Initial stiffness and the peak load are the largest in 40 mm spaced and amounted to 32 kN and 20 mm 26 kN and 0 mm 17kN. Closely spaced chords are more prone to local buckling. Mesh convergence study validated that the 10×10 mm mesh captured accurate stress gradients and local instability patterns.

**Conclusion:** ABAQUS is used to develop highly sophisticated nonlinear finite element analyses to predict the behaviour of the proposed column system subject to static loading. The static analysis shows that the 40mm chord spacing is the suitable one among the three and can withstand upto 33kN load. Overall, optimized chord spacing enhances strength and stiffness of CFS battened columns.

**Keywords:** ***Cold-Formed Steel (CFS), Finite Element Analysis (FEA), Battened column, Load carrying capacity.***

# PP-161: Decomposition based CNN-RVFLN for Load Prediction and Congestion Management in Power System

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**Introduction:** Participants from the energy market often use load forecasting to improve their trading tactics, while system managers use it to keep the grid stable. In particular, it enables system operators to take the required remedial action by helping them foresee possible power imbalances and other crucial grid circumstances. In this context, forecasting key grid conditions like congestion is more important. In order to forecast hourly time-series residual loads, this research presents a CNN-RVFLN model that employs variational mode decomposition. For major power system operations, load forecasting is crucial since loads are very unpredictable due to a variety of causes. Congestion in the electrical system is caused by disturbances with the load. Temporary supply of energy in the modern-day cause congestion along with additional system instabilities. Because the distribution system is vulnerable to a variety of events, a quicker branch flow estimate is thus required for the power system's security evaluation. By predicting any overloaded scenario in the electrical system, the hybrid capacity forecasting technique proposed in this study will aid in minimizing congestion

**Methods and Material:** Existing load forecasting models frequently struggle to handle high-frequency, non-linear grid data. While artificial intelligence models including LSTM are computationally costly and prone to overfitting with sparse data, traditional statistical models are rigid. Although they are faster, ensemble methods like XGBoost perform worse when dealing with temporal dynamics. Furthermore, signal decomposition prior to prediction is not specifically addressed by the majority of models. By combining CNN for feature abstraction, RVFLN for quick, generalized prediction, and VMD for signal preprocessing, this work closes that gap. This structured combination is a special solution for dynamic load conditions since it overcomes disturbances sensitivity, lengthy training times, along with poor generalization. **Result and Discussion**: Two distinct time frames are taken into account for load prediction; the model is evaluated for a duration of 30 minutes. In addition to predicting ahead, we also made predictions for the following day, a VMD based decomposition of the load data for the different months. In a similar way, the decomposition of the data was also carried out for data collected over a one-day period. These IMFs are provided as input to the hybrid prediction model for predicting local load, indicating a superior choice for forecasting congestion. The load prediction is also conducted for monthly and weekly durations

**Conclusion:** In this research an approach has been proposed that uses VMD-CNN-RVFLN model for prediction of local load which is the first step in congestion management of power system. The MAPE, MAE and R2 shows the accuracy of the proposed model for prediction in different intervals also. Performance comparison of the proposed VMD-CNN-RVFLN technique with other techniques for load prediction on a weekly basis for a month for the year 2022 shows that the MAPE value of the proposed model is 4.165 for the February 2022 while other models like ELM, LSTM, XGBoosting and RVFLN have a MAPE value of 7.55%,6.14%, 6.48% and 4.66% respectively. In future work the overloading situation will be handled by proposing a technique that will indicate the circuit breaker to act in advance and hence reduce any kind of congestion observed in the power station due to fluctuating voltage or any other faults that gives rise to different load condition.

**Keyword**: Variational Mode Decomposition, CNN-RVFLN, congestion management, Load forecasting

# OP-162: Workload-Aware Low-Power Network-on-Chip Architecture for Multi-Core Systems

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**Introduction**: Modern System-on-Chip (SoC) platforms integrate tens to hundreds of Processing Elements (PEs) to satisfy the growing computational demands of data-intensive applications. Traditional shared bus-based interconnects fail to scale efficiently with increasing core counts due to bandwidth contention, poor modularity, and excessive power consumption. Consequently, Network-on-Chip (NoC) architectures have emerged as a scalable and structured communication backbone for multi-core systems. Despite their scalability benefits, NoC contribute significantly to overall SoC power consumption. In modern workloads, traffic patterns are highly dynamic and non-uniform, causing many routers and links to remain underutilized while still consuming dynamic power. A major portion of this overhead arises from continuous clock switching activity in routers and links that remain idle or lightly utilized under non-uniform and dynamic traffic patterns. This motivates the need for workload-aware power optimization techniques.

**Methods and Material**: The proposed architecture targets a mesh-topology NoC integrated within a multi-core SoC environment. The NoC is logically partitioned into workload-driven clusters based on real-time traffic activity. Each cluster is categorized into one of four activity states: Sleep region, Low activity region, medium activity region, High activity region. Dynamic cluster-level clock gating is employed as the primary power optimization technique. Based on runtime workload monitoring, clock signals are selectively enabled or disabled in routers and links belonging to inactive or lightly loaded clusters. Power estimation and comparative analysis were performed to evaluate the effectiveness of the proposed approach. The methodology includes measuring dynamic power under different workload scenarios and comparing results with a conventional always-on clocked NoC architecture.

**Result and Discussion:** The proposed workload-aware clustering mechanism significantly reduces unnecessary clock switching activity in idle and low-utilization regions of the NoC. By dynamically gating clocks at the cluster level rather than individual components, the design achieves: Substantial reduction in dynamic switching power, Minimal overhead in control logic, Negligible impact on latency and throughput. The architecture effectively adapts to real-time workload variations, making it suitable for traffic-variant multi-core systems.

**Conclusion**: This paper presents a workload-aware, low-power Network-on-Chip architecture employing dynamic cluster-level clock gating based on real-time workload behaviour. By partitioning the mesh NoC into activity-driven clusters and disabling clocks in idle or lightly loaded regions, the proposed approach significantly reduces dynamic switching power while maintaining acceptable latency and throughput performance. The architecture is scalable, adaptable to varying traffic conditions, and well-suited for next-generation multi-core SoC platforms.

**Keyword:** ***Network-on-Chip, Low Power Design, Clock Gating, Workload Awareness***

# PP-163: A synthetic method for the synthesis of Tafamidis analogues and their new variants

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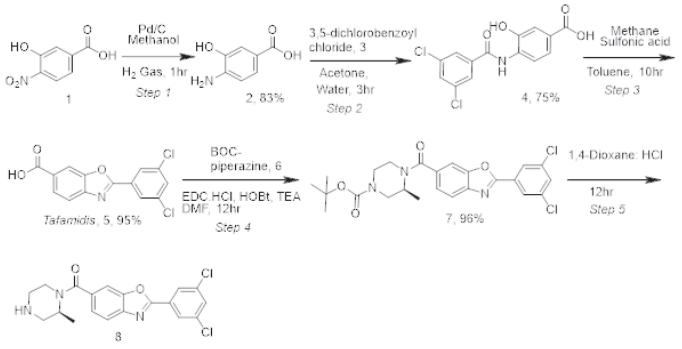
**Introduction:** The original synthesis route for tafamidis was reported by J. W. Kelly and et. al., using 4-amino-3-hydroxybenzoic acid as a starting material, leading to an overall yield of 13% in a four-step process. It has been reported that the synthesis of benzoxazole-based compounds efficiently prevented TTR amyloid formation in vitro and exhibited selective binding to TTR in blood plasma. In the continuation of our ongoing research, herein we attempted to explore an alternative synthetic strategy to synthesize novel Tafamidis and its potential analogues that could lead to active pharmaceutical ingredients (API).

**Methods and Materials:** 3-Hydroxy-4-nitrobenzoic acid and 3,5-dichlorobenzoyl chloride are used as cheap and easily accessible starting materials. Upon palladium-catalysed reduction, these materials generated substantial intermediates for acid-catalysed cyclisation, leading to 2-(3,5-dichlorophenyl) benzo[d]oxazole-6-carboxylic acid (Tafamidis). In addition, the Tafamidis moiety also underwent in the coupling reactions to produce several analogues. These are characterized by standard techniques like FT-IR, NMR, and HRMS.

**Result and Discussion:** An alternative synthetic route to efficiently synthesize a series of novel Tafamidis derivatives is presented in Scheme-1. This strategy employs cost-effective, multi-step procedures using inexpensive and readily available reagents and catalysts, resulting in the targeted Tafamidis analogues with good yields. Additionally, the approach was expanded to synthesize various amide derivatives with diverse functionalities, potentially exhibiting significant biological activity. Compared to existing synthetic methods, this approach offers a promising alternative by minimizing the regeneration of intermediates and reducing reliance on excessive metal-catalysed coupling reactions.




Scheme 1. Multi-step synthesis of Tafamidis and its analogues.

**Conclusion:** An alternate synthetic approach demonstrated as a novel approach for synthesis of Tafamidis analogues. The present procedure offers an efficient, practical, and cost-effective synthetic method to achieve the important scaffold and its extended amide derivatives that may exhibit several biological activities. Furthermore, the strategy has been executed by using affordable reagents, easily available intermediates, and fewer conversion steps, leading to a good yield of the desired compounds.

***Keywords: $ZrOCl_2$, TOA, Cyanex 923, Kerosene.***

# PP-164: Detecting Cyber Threats in Internet of Medical Things (IoMT) Networks using Random Forest Classification

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**Introduction:** The deployment of Internet of Medical Things (IoMT) devices fundamentally transforms smart healthcare but introduces severe cybersecurity vulnerabilities, exposing resource constrained systems to life-threatening cyberattacks like Denial-of-Service (DoS) and malicious spoofing. Because traditional rule-based intrusion detection systems (IDS) struggle to parse complex, high volume healthcare network traffic, a scalable machine learning framework utilizing ensemble tree-based classification is proposed to accurately distinguish benign interactions from adversarial threats.

**Materials and Methods:** To address this challenge, the methodology leverages the CIC IoMT Dataset (2024), which captures realistic communication patterns and cyberattacks within a simulated healthcare testbed. During preprocessing, raw PCAP network traffic is transformed into structured, flow-based statistical features. The experimental pipeline utilizes 7,160,831 training and 1,614,182 testing instances across 46 distinct attributes. Categorical protocol features are encoded via standard label transformation. To model complex non-linear decision boundaries, a Random Forest classifier parameterized with 100 parallel estimators is deployed and optimized for multi-core execution to efficiently process the high-dimensional data.

**Results and Discussion:** The Random Forest model demonstrated exceptional aggregate performance, achieving an overall test accuracy of 99.61% and a weighted F1-score of 1.00. The classifier exhibited perfect precision and recall (1.00) across all high-volume volumetric attacks, including DDoS ICMP, DDoS TCP, DDoS UDP, and DoS Connect Flood, effectively neutralizing brute-force network disruptions. However, a deeper analysis via the macro-average metrics (Precision: 0.95, Recall: 0.90, F1: 0.91) and the resulting confusion matrix revealed notable vulnerabilities in detecting stealthy, low-footprint attacks. Most critically, the model struggled with "Recon VulScan," yielding a severely degraded recall of 0.30 and an F1-score of 0.44, frequently misclassifying these exploratory packets. Similarly, "OS Scan" (Recall: 0.67) and "ARP Spoofing" (Recall: 0.83) showed performance drops. This highlights a classic vulnerability in frequency-based machine learning models where extreme class imbalance heavily biases the model toward dominant volumetric attack signatures while missing subtle reconnaissance vectors.

**Conclusion / Recommendations:** The proposed framework establishes a highly effective operational baseline for mitigating high-volume cyberattacks in smart healthcare infrastructures. While the system ensures computational efficiency and robust detection of DoS/DDoS vectors, the generalization gap concerning minority reconnaissance classes poses a continuous risk for early-stage threat detection. To ensure comprehensive patient safety, future iterations must address these blind spots. Implementing advanced synthetic oversampling techniques like SMOTE for minority classes, exploring deep sequence models (e.g., LSTMs) to capture the temporal nature of reconnaissance scans, and applying cost-sensitive learning to penalize false negatives are proposed to yield a more resilient diagnostic tool.

**Keywords:** Healthcare Cybersecurity, Internet of Medical Things (IoMT), Intrusion Detection Systems (IDS), Random Forest, Network Traffic Analysis, Threat Intelligence.

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