Institute of Engineering & Management
School of University of Engineering and Management Kolkata

Advances in Waste Management and Resource Utilization

4th International Conference on Sustainable Waste Management 2025

Abstract Book

Proceeding of the International Conference on Sustainable Waste Management

12th - 14th September, 2025

Chief Editor
Rahul Baidya
Editor
Anirban Mukherjee
Somdipta Bagchi

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Proceeding of the
4th International Conference on Sustainable Waste Management
(ICSWM-2025)
12th – 14th September 2025

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Proceeding Abstract Book of 4th International Conference on Sustainable Waste Management (ICSWM-2025)

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Preface

It is with immense pleasure that I present the Proceeding Abstract Book of the 4th International Conference on Sustainable Waste Management (ICSWM-2025), held from 12th to 14th September 2025. This volume of abstracts presents an extraordinary range of contributions from academician, researchers, industry experts, and policymakers.

With rapid urbanization, haphazard industrial growth, and expanding consumer base there has been enormous pressure on natural resources and waste management systems worldwide. At the same time, the climate challenges demand the transformation of linear economy to circular economy models, where waste is seen as a valuable resource not as a burden. Against this backdrop, ICSWM-2025 presents a vibrant forum for dialogue, innovation, and collaboration.

This abstract book captures a diverse collection of research from circular economy to waste management. The study ranges from the valorization of industrial by-products such as fly ash, red mud, and hatchery waste, to emerging technologies including plasma gasification, microbial fuel cells, nanomaterials for remediation, and AI-driven smart systems. They reflect an inspiring blend of traditional research areas and cutting-edge findings. A significant portion of the contributed abstracts focuses on biomass, agro-waste, and floral residues utilization. Studies on pyrolysis, biochar, pelletization, and biofuel production provide circular pathways for renewable energy generation, while mitigating environmental challenges. Similarly, construction and demolition waste, e-waste, and wastewater management emerges as a central theme which underscores the need for scalable technologies and robust policies to manage rapidly growing urban waste management challenges.

It is also to be noted that this collection also emphasizes the interdisciplinary character of sustainable waste management. Technological innovations are complemented by studies in economics, policy, urban planning, and behavioral science. For example, analyses of circular economy models, human resource strategies for sustainability, and the integration of AI reveal the multi-dimensional nature of this field. Such integration is essential, as technical solutions alone cannot succeed without social acceptance, economic feasibility, and institutional support.

The conference also serves as a platform for young researchers and scholars to engage with global experts. The abstracts submitted by early-career scholars showcase not only technical rigor but also creativity in addressing local issues and challenges. Their contributions remind us that sustainability is as much about grassroots innovation as it is about high-end technology. The collaborative spirit of ICSWM-2025 is reflected in the international representation in this abstract book. Contributions from India, Europe, the Middle East, and beyond demonstrate the global dimension of circular economy and challenges in waste management, while also offering region-specific studies and insights. This cross-cultural exchange of ideas and knowledges enriches our understanding and accelerates the adaption of circular economy across borders.

I would like to extend my heartfelt gratitude to the Chief Patron, Chairman, Co-Chairman, Scientific Committee, and Organizing Committee members, whose vision and tireless efforts have made this conference possible. Special thanks are due to the authors who shared their research, and to the reviewers who ensured the quality of the proceedings. The Office of Sustainability and the Department of Mechanical Engineering at the Institute of Engineering & Management, School of University of Engineering and Management, Kolkata, deserve particular recognition for their dedicated support.

This editorial would be incomplete without acknowledging the larger purpose that binds us. Waste management is not merely a technical or administrative problem, —it is fundamentally about environmental responsibility towards sustainable future. Each abstract in this book represents a small but vital step toward reducing environmental footprints, protecting ecosystems, and creating resilient and inclusive communities. Together, they reinforce the theme that sustainable waste management is integral to achieving the United Nations Sustainable Development Goals (SDGs)**.**

As you read through the pages of this volume, I encourage you to view them not only as scientific contributions but as building blocks of a collective vision. A vision where industries adopt circular practices, cities become regenerative, and individuals embrace responsibility for the resources they consume thus adopting the circular economy in its true sense.

Prof. (Dr.) Rahul Baidya
Editor in Chief

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Abhishek Nayak, Cheera Anubhav Nayak, Guda Sridevi, Janarul Shaikh*
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Abstract

Two industrial waste products that are readily available in India, red mud (RM) and fly ash (FA), need to be recycled for economic and environmental reasons. Numerous studies have recently been conducted globally to determine suitable sites for the repurposing of these waste materials. The compaction properties of different FA and RM combinations, however, have not been extensively studied. The primary objective of this study is to ascertain if FA and RM can be used to construct road subgrade in circumstances when a higher level of compaction is necessary in terms of maximum dry density (MDD) and optimum moisture content (OMC). In the study, test observations of the compaction parameters for four distinct RM and FA mixtures including 10%, 20%, 30%, and 40% FA were investigated. This study demonstrates a steady decline in both MDD and OMC as the FA% rises. It shows that the RM-FA combinations are gradually losing their strength. It could be explained by the acid-base reaction that occurs when acidic FA particles bind firmly to basic RM particles. Therefore, the research supports the use of FA and RM as subgrade in areas like village roads where more strength is not needed. However, before being implemented in practice, more research on FA-RM combinations should be done.

Keywords: Industrial Waste; Fly ash; Red mud; Road subgrade; Compaction characteristics.

PAPER-ID-002

Investigation on Compaction Characteristics of Red Mud and River Sand Mixes to Be Used as Road Subgrade

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Abstract

For subgrade construction, red mud (RM), an industrial waste that is easily accessible in significant quantities in India, can be utilized instead of sand, which is becoming more and more expensive every day. Many studies that examined different aspects of RM for reuse in conjunction with various additions, including fly ash, lime, gypsum, cement, quarry dust, etc., can be found in the literature. Not much research has been done on the compaction properties as one of the important geotechnical properties of combinations of red mud and river sand (RS). The primary goal of this study is to evaluate the compaction properties of different RM and RS mixes. Compaction test results for four distinct RM to RS ratios (10:1, 10:2, 10:3, and 10:4) made by combining 10%, 20%, 30%, and 40% of RS with respect to dry mass of RM were examined in the study. The study found that the optimum moisture content of RM gradually decreased as the RS addition increased, although the maximum dry density increased gradually. This indicates a steady increase in the strength of the RM-RS combinations. This study promotes the reuse of red mud along with the river sand as road subgrade materials where significant strength is not required. However, more research on red mud and river sand mixes should be conducted before implementation.

Keywords: River sand; Red mud; Road subgrade; Compaction parameters.

PAPER-ID-005

Comparative Evaluation of CI Engine Performance Using Argemone Mexicana Oil-Diesel Blends (B20–B60)

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Abstract

Biodiesel is a promising substitute as an alternative fuel, which has gained significant attention due to the predicted shortness of conventional fuels and environmental concern. The utilization of liquid fuels such as biodiesel produced from ARGEMONE MAXICANA by transesterification process represents one of the most promising options for using conventional fossil fuels. The Argemone Maxicana oil is converted into Argemone Maxicana oil methyl ester known as biodiesel, prepared in the presence of a homogeneous acid catalyst. The physical properties such as density, flash point, kinematic viscosity, Cloud point, and Pour point were found for Argemone Maxicana oil. The same performance, combustion, and emission study were carried out for bio-diesel and the diesel fuel for obtaining the baseline data for analysis in a compression ignition engine at a constant compression ratio of 17.5. Performance parameters like BSFC, BTHE and EGT are better than diesel. According to combustion parameters like maximum cylindrical pressure, rate of pressure rise, NHR, CHR and MBF, we got most promising values for bio-diesel. Bio-diesel emits fewer amounts of CO, CO_2, and HC in comparison to diesel. The values obtained from the Argemone Maxicana methyl ester are closely matched with the values of conventional diesel and can be used in the existing diesel engine with or without any modification.

Keywords: Compression ignition engine; Compression ratio; BSFC; BTHE; NHT; CHT.

PAPER-ID-007

Investigation on Industrial and Construction Waste Management Strategies for Sustainable Development-A Review

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Abstract

Continuous population growth and their requirements causes rapid and haphazard industrialization and disposal of waste materials from construction sector and industry has become changeling task for the engineers. Industry plays a vital role for the development of the society and it is one of the largest major sources for producing variety of new products. Waste production is an inevitable outcome of the developmental activities. The end product of processing of raw materials for the manufacture of new products results as industrial waste. Waste is the useless by product of human activity from different industries. If the value of the product is not commercialized then it is difficult to dispose it. The non-commercialized end part of the product is treated as waste materials. The improper disposal of waste leads to high risks for human being and surrounding environment. In the present research an attempt has been made to study the better waste management strategies and its applications for the sustainable development of society. The present mainly focus on review on industrial and construction waste management strategies and addresses the different methods of industrial waste, demolition waste, construction waste, mining waste and agricultural waste for the sustainable development of society. The present paper investigates on the applications of both different methods of disposal and management related to industrial, household, before and after production. This study will be helpful to understand the concept of industrial and construction waste and its applications for their effective utilization to minimize the greenhouse gas emissions and makes sustainable management strategies.

Keywords: Construction waste; Environment; Industrial waste; Management strategies; Sustainable Development.

PAPER-ID-008

Assessment of PRF of Indian Major Ports- A Step towards Achieving UNSDG 14

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Abstract

The management of waste received from ships at Indian ports plays a significant role towards the sustainable development of the maritime industry and aligns with the United Nations Sustainable Goals. Port Reception Facilities (PRFs) are arrangement that any port should offer for the collection of operational discharges like oily mixtures, residues, and garbage generated from a seagoing vessel. There was inadequate research that investigated the adequacy of PRF for Indian ports. Thus**,** examining the adequacy of PRF in the ports of India with an emphasis on major ports is the aim of the study. The barriers to the effective management of waste in the major ports are also identified in the study from PRF plans of major ports of India, reports published by DG Shipping and Indian Port Association (IPA), and secondary data published by various journals and research articles. In the study, a qualitative approach is used. Along with that, the study finds that Indian major ports are required to provide more types of PRF for MARPOL compliance. Only 38% of the Advance Notification Forms (ANF) were converted into the delivery of waste in Indian ports for the calendar year 2022. Further, the study explores the policy initiatives like Ministry of Ports, Shipping, and Waterways (MoPSW) implemented and offers recommendations, such as the adoption of green technologies to optimize PRF in India.

Keywords: Port Reception Facilities; Sustainable development; Inadequacies; Waste Handling.

PAPER-ID-009

Numerical Analysis of Thermo-Chemical Reactions in Plasma-Based Solid Waste Gasification

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Abstract

This research paper presents a detailed simulation of chemical reactions during plasma gasification of solid waste using ANSYS FLUENT. Plasma gasification is an advanced method that converts solid waste into valuable syngas a mixture of hydrogen (H_2) and carbon monoxide (CO) by applying high-temperature plasma to break down waste at the molecular level. In this study, a 2D numerical model was developed to replicate the gasification process, integrating MagnetoHydroDynamics (MHD) and electric potential modules to simulate plasma ionization, along with combustion dynamics. The PISO algorithm was used to couple pressure and velocity under compressible flow conditions, while Large Eddy Simulation (LES) resolved turbulence effects. An Eulerian–Lagrangian framework captured interactions between gas and solid particles, with the reaction continuity managed across multiple particle injections. Key processes like combustion and gasification were modeled using the Flamelet model, and radiative heat transfer was addressed by the Discrete Ordinates (DO) radiation model. The simulation analysed how variations in temperature, pressure, and plasma energy influence chemical reactions within the reactor. Results revealed that higher plasma temperatures significantly improve waste decomposition and enhance syngas production. Furthermore, the study highlights the critical role of heat transfer, flow dynamics, and chemical kinetics in determining overall reactor performance. The insights gained from this simulation provide valuable guidance for optimizing reactor design, improving energy recovery, and minimizing environmental impact. Overall, this research demonstrates the effectiveness of simulation tools like ANSYS FLUENT in advancing the development of plasma-based waste-to-energy systems.

Keywords: ANSYS FLUENT; Plasma gasification; Waste disposal system; Plasma reactor simulation.

PAPER-ID-010

Integrating Smart Waste Management with Regenerative Urban Practices: A Scalable Model for Kochi

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Abstract

Globally, the management of waste has become a significant challenge in urban areas, with more than 2 billion tons of municipal solid waste generated each year. This amount is expected to increase considerably, posing risks to environmental sustainability and the quality of urban life. Concurrently, discussions in urban planning have started to incorporate the principles of regenerative urbanism - a framework that seeks not only to maintain but also to rejuvenate ecological systems and enhance community welfare. Nevertheless, the relationship between waste management and regenerative urban approaches is still inadequately explored, especially in rapidly urbanizing and ecologically vulnerable-regions. This study seeks to bridge that gap by developing an optimized and scalable model that integrates Smart Waste Management technologies with regenerative urban practices in the city of Kochi, Kerala. The city faces growing challenges related to waste volume, inefficient collection, transportation issues, and overburdened central processing systems such as Brahmapuram. Through spatial analysis, stakeholder consultations, and ward-level surveys in 10 selected high-density wards, the research identifies key inefficiencies across bio and non-biodegradable waste streams. The proposed intervention includes (1) decentralized bio-waste-to-energy plants, (2) Smart MCFs with IoT and AI-assisted segregation, and (3) a centralized MRF and RDF unit. A detailed cost-benefit analysis indicates over 80% landfill diversion, significant carbon footprint reduction, and employment generation for informal workers. This integrated model supports circular economy principles and demonstrates how regenerative urban systems can be enabled through smart, inclusive, and context-specific waste solutions.

Keyword: Smart waste management; Regenerative cities; Decentralized waste systems; Circular economy.

PAPER-ID-013

Towards Sustainable Green Waste Collection: A Fuzzy Evaluation of Compostable Packaging

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Abstract

This study redefines the criteria of a "practically compostable bag" in sustainable municipal green waste management by integrating real-world usability parameters. Using a fuzzy logic approach, two core dimensions are modeled: collection suitability (resistance over time during waste storage) and compostability (degradation speed in composting facilities). A third input-price-is incorporated based on manufacturer data, forming the basis of fuzzy sets for "cheap," "acceptable," and "expensive" categories. Field data from 46 composting sites in Hungary between April and June 2025 informed the fuzzy classification of composting time. Meanwhile, collection performance data from waste service providers enabled fuzzy modeling of in-bin durability. The system was implemented and simulated using MATLAB's Fuzzy Logic Toolbox. A Mamdani-type inference engine was constructed with 27 expert-defined rules and centroid-based defuzzification. The model outputs a suitability score interpreted through three categories: Low, Moderate, and High Suitability. Bags achieving at least two favorable (low) input characteristics-such as low price and quick degradation—while the third remains no worse than medium, are categorized as High Suitability, with scores in the range of 0.71–1.00. This fuzzy framework enables decision-makers to assess compostable packaging performance under uncertainty, balancing environmental efficiency and economic feasibility.

Keywords: Compostable packaging; Fuzzy logic; MATLAB; Mamdani.

PAPER-ID-014

The Role of LCA in Green Marketing Strategies for Electric Vehicle Innovation and Development

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Abstract

Electric mobility is expanding worldwide in response to growing environmental challenges. This study aims to clarify and quantify the characteristics of "green" innovation, establishing a foundation for evaluating the viability of emerging electric vehicle (EV) technologies. It emphasizes the importance of component-level comparisons during EV production, focusing on attributes that influence consumer preferences—particularly measurable reductions in carbon emissions. The paper applies Life Cycle Assessment (LCA) to analyze two widely used electric motor types in EVs: Asynchronous Motors (ASM) and Permanent Magnet Synchronous Motors (PSM). Twelve motors were evaluated using the GWP100 indicator, expressed in kg CO_2 equivalent, and modeled in GaBi 4.0 software. Results reveal that PSM motors, which rely on rare earth elements, produce approximately 2.5 times more CO_2 emissions than ASM motors during manufacturing. These findings highlight the environmental trade-offs associated with innovation choices and reinforce the value of sustainable product development. They also demonstrate the relevance of environmental performance data in shaping green marketing strategies for electric vehicles. By linking sustainability metrics with tangible product characteristics, the study offers a practical framework for supporting more informed consumer behavior and policy-making.

Keywords: LCA; Green marketing; Green innovation; Electric vehicles.

PAPER-ID-016

Green Energy Generation from Pellets of Garden Waste and Organic Additives

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Abstract

India produces approximately 62 million tonnes of municipal solid waste (MSW) each year, with garden waste constituting about 12–15% of this total. Although biodegradable, the garden waste is frequently mishandled via open dumping or composting resulting in methane emissions, air pollution, and the depletion of valuable biomass. Pelletization of the garden waste needs to be explored. This research concentrated on the creation of entirely organic biomass pellets from biodegradable, locally sourced resources, with garden waste as the principal feedstock. The range of additives includes coconut husk, cow manure, sawdust, and molasses. Standardised protocols were employed to assess essential physico-chemical and thermal characteristics, encompassing moisture content, ash, total volatile solids, and calorific value. Eight blends were developed and evaluated through both theoretical and practical methods. The ideal formulation was determined to be 60% garden waste, 20% coconut husk, 5% cow dung, 10% sawdust, and 5% molasses. The pellets derived from this mix attained a calorific value of 3807.98 kcal/kg, moisture content of 10.46%, ash content of 8.33%, and bulk density of 0.72 g/cm³, in accordance with ISO/ENplus requirements. CHNS examination revealed carbon at 43.38%, hydrogen at 6.423%, nitrogen at 0.89%, and sulphur at 0.251%. Although carbon was marginally below and sulphur marginally above optimal levels, all values remained within acceptable parameters for non-woody biomass. This initiative provides a viable and scalable alternative for decentralised biomass energy through the conversion of garden waste into clean biofuel. It bolsters national renewable energy objectives and promotes UN Sustainable Development Goals 7 (Affordable and Clean Energy), 12 (Responsible Consumption and Production), and 13 (Climate Action).

Keywords: Garden waste additives; Pelletization; Calorific value; Optimization.

PAPER-ID-017

Biomass Supply Chain: Conversion of Floral Waste to Value-Added Product

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Abstract

India is a country of religious beliefs and numerous rituals where various flowers play a very vital role. As per the survey, India produces over 300 tons of floral waste every day. The floral waste is often directly disposed into the water bodies causing deterioration of water quality and a negative impact on the aquatic life. Valorization of floral waste to revenue-earning utility products can be done by extraction of essential oils from the floral waste, which, after proper purification can be used for formulating perfumatory products, skincare products, aromatherapy and pharmaceuticals. Traditional methods, namely, hydro-distillation, effleurage extraction and solvent extraction have been used for centuries in oil extraction while the modern methods, namely, microwave-assisted extraction (MAE), ultrasound-assisted extraction (UAE) and supercritical CO_2 extractions are currently employed to accelerate the extraction process.

Rose (*Rosa*) and jasmine (*Jasminum*) are the most common flowers used for decorations and marriage ceremonies. The present investigation reports the procedure for essential oil extraction from rose and jasmine using a traditional technique, namely, solvent extraction (SE) using ethanol and a modern technique, namely, ultrasound-assisted extraction (UAE). The physico-chemical parameters, namely, temperature, pH of the medium, time of extraction are optimized for obtaining the maximum yield of oil in both the processes. The essential oil is further used in the formulation of usable perfume products with rose oil serving as the base note, jasmine oil as the middle note and citrus fragrance as the top note alongwith an appropriate fixative agent to improve its lasting time and the solution was bottled and kept at room temperature in a dark corner.

Keywords: Floral waste; Essential oil; Solvent extraction; Ultrasound-assisted extraction; Perfume.

PAPER-ID-018

Solvent Extraction of Molybdenum from the Leach Liquor of Refinery Waste Catalysts Using Ionic Liquid as an Organic Extractant

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Abstract

Waste petroleum catalysts (WPC) contain different valuable metals such as Mo, Ni, and V. Hydrometallurgical methods have been reported to recover metals from WPC; however, their effective separation from the leach liquor is a challenge. This work thus aims to study the solvent extraction (SX) of Mo from the leach liquor of WPC using ionic liquid as an organic extractant. An ionic liquid, Cyphos IL 101 (trihexyl(tetradecyl)phosphonium chloride), diluted in kerosene, was used to selectively extract Mo from the WPCs leach liquor containing Al, Ni, Mo, and V. The SX experiments were conducted using refinery leach liquor (containing citrate anion) of varying pHs (0-3) to understand the effect of aqueous medium pH on extraction efficiency and selectivity. The other parameters (Cyphos IL 101 concentration of 0.25 molar, reaction period 5 min, organic to aqueous ratio 1:1, reaction temperature 25 °C) were constant. The results indicated that Cyphos IL 101 was a highly effective organic extractant, and aqueous pH was a vital parameter that affected Mo extraction yield and selectivity. Cyphos IL 101 was able to extract Mo (88.0-99.6%) at all studied liquor pHs; however, at aqueous pHs beyond 0, the co-extraction of Ni and V increased significantly, which negatively impacted the selectivity of the process. On the contrary, the co-extraction of other metals (Mo, V, and Al) at low aqueous pH 0 was negligible (<5%). The findings suggest Cyphos IL 101 is a highly effective extractant for Mo from WPCs liquor at low aqueous pHs.

Keywords: Waste catalysts; Solvent extraction; Ionic liquid; Recycling.

PAPER-ID-019

Design and Experimental Analysis of Mechanized Eggshell-Membrane Separation System for Hatchery Waste

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Abstract

Owing to increased egg consumption, the chicken farming industry is continuing to grow globally which leads to quantum generation of hatchery waste mainly eggshell debris. The eggshell contains thin membrane, a semi-permeable layer located between the eggshell and egg white which is a rich source of bioactive compounds such as collagen, glycosaminoglycan and proteins. Collagen obtained from the egg membrane is an essential protein that can be utilized as wound care material. These calcium rich extremely important commodity is generally dumped into landfills, leading to various environmental problems. The scientific processing of waste egg shell and membrane can have biomedical and industrial applications as value-added products. The present study aims towards development of a mechanized system for the separation of membrane from hatchery eggshells. A laboratory scale prototype has been designed and developed for Eggshell-Membrane Separation. The separation of eggshell and membrane are done through high pressure water jet and flotation method. The system comprises of a rotary cylindrical reactor where water jet nozzle is fitted on the top. High pressure water jet at 7-10 bar is applied over the broken egg shells while the cylindrical reactor is rotating at slow speed. The high pressure water jet separates the membranes from crushed eggshells and start to rise towards free surface leaving behind shells at the bottom. Then the reactor is tilted to take out the floated membrane over the strainer. The egg shells are collected from the bottom by opening the gate valve. Experiments were conducted for mechanized separation of egg-shell and egg-membrane where segregation efficiency of 85-90% could be achieved. The findings of this study contribute for the development of mechanized, sustainable and environment friendly methods for utilization of hatchery waste.

Keywords: Hatchery waste; Eggshell membrane separation; High pressure water jet; Mechanized segregation.

PAPER-ID-029

A Bibliometric Analysis on Trends of Research on Epoxy-Waste Rubber Composite

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Abstract

Epoxy-waste rubber composites are significant materials in various industrial and engineering applications due to their unique combination of properties and sustainability. Numerous studies have been carried out by researchers to elucidate various aspects of waste rubber-toughened epoxies. The current investigation finds the bibliographic analysis of the work on epoxy-waste rubber composites. The Scopus-based database has been taken, and analysis has been done based on the article published on plain epoxy-waste rubber composites and using other additional substances in these composites for additional benefits. The findings from the analysis explore the importance of waste rubber-epoxy composites and suggest the probable future work that can be done for the betterment of the composite and environmental benefits.

Keywords: Waste-to-energy; Sustainability.

PAPER-ID-031

Properties of Oil and Char Derived from Slow Pyrolysis of Different Biomass at Different Conditions

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Abstract

This study aims at identifying the characteristics of oil and char produced as a result of slow pyrolysis of two crop wastes rice husk and wheat husk under varied particle sizes, temperatures, and pre-treatment. The primary objective was to compare High Heating Value (HHV) and quality of fuel of the pyrolysis product in order to ascertain the best conditions for optimum energy yield. The biomass was subjected to composting, acid hydrolysis, and alkaline hydrolysis and then paralyzed at temperatures of 300°C to 550°C with particle sizes of 150 µm, 300 µm, and 600 µm. The results indicated that lower particle size and increased temperature provided increased oil yield and quality. Out of all, composted rice husk at 550°C and 150 µm size provided maximum oil yield (42.8%) and HHV of 25.3 MJ/kg and was thus the best condition. Acid and base treatment enhanced the fuel quality by minimizing lignin and maximizing cellulose, which facilitated improved thermal breakdown. The char obtained under alkaline hydrolysis revealed the maximum HHV (28.6 MJ/kg), improved fixed carbon, and minimum ash content, which renders it a good solid fuel. Wheat husk produced lower HHV values than rice husk under identical conditions. This research evidently demonstrates that the energy content and quality of oil and char strongly vary with particle size, temperature, and treatment of biomass. These results will aid in the selection of the optimal biomass type and condition for efficient biofuel generation in Indian industries.

Keywords: Slow pyrolysis; High Heating Value; Rice husk; Wheat husk; Biomass pre-treatment.

PAPER-ID-032

Performance of Low-cost Concrete Using Paper Waste: A Review Towards Sustainability

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Abstract

The world is facing a pressing issue of waste management, with landfills reaching or exceeding capacity, resulting in increased disposal costs and environmental hazards and waste generation growing at 5% annually. Traditional cement production makes things worse, so we need new ideas. This study investigates the potential of utilizing waste materials generated from paper industries, such as Papercrete, Hypo Sludge, and fly ash, as alternatives to cement and aggregates in concrete production. A comprehensive review of existing literature reveals that incorporating waste paper pulp, specifically Hypo Sludge and Paper Sludge Ash, as a cement replacement can enhance concrete strength. Notably, replacing cement with up to 10% waste paper pulp improves properties like compressive, flexural, and splitting tensile strength. However, higher proportions of waste paper pulp lead to reduced strength. The study also highlights the economic and environmental benefits of using waste materials in concrete production. Cost analysis indicates potential savings of up to 16%, while energy consumption is reduced by over 24%. By integrating industrial waste materials into concrete production, the construction industry can mitigate waste disposal challenges and contribute to sustainable development. The findings of this study underscore the potential for waste materials to be repurposed in concrete production, supporting a more environment friendly and sustainable future for the construction industry.

Keywords: Hypo sludge; Paper sludge ash; Sustainability; Low cost concrete; Waste management.

PAPER-ID-042

MATLAB-Based Simulation Framework for Agro-Waste Conversion to Bioenergy and Bioproducts

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Abstract

The agricultural sector generates substantial amounts of waste, posing significant environmental and economic challenges. The present work proposes a theoretical framework for valorizing agro-waste into bioenergy and bioproducts using MATLAB simulations. By modelling and simulating various conversion technologies, such as anaerobic digestion, fermentation, and pyrolysis, MATLAB can be used to predict process outcomes, optimize operating conditions, and identify potential bottlenecks. This theoretical approach can help evaluate the feasibility of different agro-waste valorization pathways, including the production of biofuels, biogas, bio-oil, bioplastics, biochemicals, and biofertilizers. The use of MATLAB simulations can facilitate the design and optimization of bioprocesses, reducing the need for experimental trials and accelerating the development of sustainable agro-waste valorization systems. This paper discusses the theoretical foundations of agro-waste valorization, highlighting the potential benefits and challenges associated with using MATLAB simulations to model and optimize these systems. The findings of this research work suggest that a theoretical approach using MATLAB can provide valuable insights into the design and operation of agro-waste valorization systems, contributing to a more sustainable and circular economy. By optimizing process conditions and predicting process outcomes, MATLAB simulations can help reduce the environmental impacts associated with traditional waste management practices, while also generating economic benefits for farmers and rural communities. Furthermore, this paper highlights the potential for MATLAB simulations to be used in conjunction with experimental trials to validate model predictions and further optimize agro-waste valorization systems. Overall, the present research work demonstrates the potential of MATLAB simulations to play a key role in the development of sustainable agro-waste valorization systems.

Keywords: Agro-waste valorization; Bioenergy; Bioproducts; MATLAB simulation; Sustainable development.

PAPER-ID-043

Sustainable Wastewater Treatment Using Hydroponic System Cultivating Stinging Nettle in Himachal Pradesh, India

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Abstract

Water pollution from various sources of water such as textile, agriculture, domestic, municipal etc., poses a significant threat to ecosystems due to the presence of toxic dyes, heavy metals, and persistent organic compounds. Phytoremediation which is a green and sustainable technology that uses plants to clean polluted environments by removing or neutralizing harmful contaminants. It is a cost-effective method that eliminates the need for expensive chemical or mechanical treatments. The study highlights the potential of *Urtica dioica* (stinging nettle), a native plant species abundantly found across Himachal Pradesh, for wastewater treatment through hydroponic phytoremediation. *Urtica dioica* for its rapid growth, adaptability, medicinal value, and high heavy metal uptake capacity, stinging nettle offers a sustainable and locally available solution. A coconut-coir-based hydroponic system was custom-designed and operated under controlled conditions using untreated wastewater. The approach presents an eco-friendly, low-cost method for treating both rural and urban wastewater. Comprehensive physicochemical and biological analyses were conducted pre and post-treatment following APHA and IS protocols. The system demonstrated significant removal efficiencies, with cadmium (Cd) reduced by 84.62%, zinc (Zn) 92.31%, lead (Pb) 93.33%, BOD 90.32%, and COD 80.26%. There were also noticeable improvements in appearance, such as reduced turbidity, colour, and odour. Compared to conventional methods that require high energy and complex infrastructure, this phytoremediation approach is cost-effective, low-maintenance, and eco-friendly. The results highlight the strong pollutant removal capacity of *Urtica dioica*, including significant heavy metal uptake and reduction of organic pollutants, reinforcing its potential as a native hyperaccumulator and demonstrating the effectiveness of hydroponic systems for sustainable wastewater treatment in Himachal Pradesh.

Keywords: Contaminants; Phytoremediation; Hydroponic system; Stinging nettle; Native; Heavy metal sustainability.

PAPER-ID-046

Batch Cooling Crystallisation of Sulfanilamide in Deep Eutectic Solvents

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Abstract

Selection of solvent in industrial crystallization of Active pharmaceutical ingredients (API) plays a crucial role in determination of the end properties and to obtain desired crystal size distribution. The choice of solvent and the crystallization process parameters contribute to improvement in desired material properties such as stability, bioavailability, particle size, crystal habit and polymorphic form of the product. Few studies have explored the application of DES to crystallization of pharmaceutical compounds. Sulfanilamide is widely used pharmaceutical in health care and cosmetics due to its anti-bacterial properties and is chosen for study on crystallization in deep eutectic systems. The study involved investigation and identification of a suitable DES as a crystallization medium for crystallization of sulfanilamide. Experiments were done to determine the metastable zone width (MSZW) for unseeded batch cooling crystallization of sulfanilamide in DES prepared from choline chloride salt as a hydrogen bond acceptor in combination with glycerol as H-bond donor. Results of experimental investigation are reported for which no experimental data were previously available on investigation with different molar ratios of HBA: HBD (1:1, 1:2 and 2:1) at different cooling profiles (i.e. 323.15K to 278.15K).

Metastable zone width was determined for the system of sulfanilamide dissolved in DES mixture of choline chloride and glycerol with 1:1 and 1:2 ratio respectively by varying the super saturation and detecting the nucleation event by continuous cooling of supersaturated solution at constant rate. Crystals were obtained under varying conditions and the particle size distribution was obtained by sieve analysis method. The crystal mean size was determined using an optical microscope. Crystals obtained were characterized using the X-ray diffraction method. Average crystal size was calculated using the Debye-Scherer method.

DES studied in this work are stable as homogeneous liquid at room temperature and exhibit a greater solubility advantage of sulfanilamide compared to that of water and methanol as solvents. Better solubility advantage of sulfanilamide was noted in choline chloride: glycerol (1:1) compared to choline chloride: glycerol (1:2) solvent and all other molar ratios including solvents prepared in combination with water. Crystals exhibit smoother surface, are cuboidal in shape with well-defined edges, and uniform in size.

Keywords: Batch cooling crystallization; Deep eutectic solvents; Choline chloride and glycerol; Sulfanilamide; Metastable zone width and crystal growth.

PAPER-ID-048

A Comprehensive Review on Cathodic Advancements and Performance Enhancement in Microbial Fuel Cells

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Abstract

Microbial Fuel Cells (MFCs) are an emerging and promising technology capable of simultaneously treating wastewater and generating renewable bioelectricity. The performance and operation of MFCs are influenced by a range of interrelated factors, with the cathode being one of the most critical components. In recent years, growing interest has been directed toward improving cathodic performance, as it remains a major bottleneck in achieving high power output and long-term operational stability. This review provides a detailed account of MFC operating principles, mechanisms, applications, and, most importantly, the various cathodic modifications developed to enhance system performance. Although significant progress has been made in optimizing anode materials and microbial communities, this review focuses specifically on cathode-centered advancements aimed at improving electricity generation, wastewater treatment efficiency, and economic scalability. Conventional cathode materials, such as platinum-based catalysts, while effective, are expensive and highly susceptible to fouling in real wastewater conditions. As a result, recent research has shifted toward the development of alternative cathode materials and modification strategies that are both cost-effective and performance-enhancing.

Keywords: Microbial Fuel Cell; Cathode Modifications; Wastewater Treatment; Alternative Catalysts; Platinum-Free Electrodes; Electrocatalytic Performance.

PAPER-ID-049

Temporal-Spatial Modeling of Global Climate: A Graph Neural Network Approach to Temperature and CO_2 Prediction

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Abstract

Climate change, caused by rising temperatures and higher CO_2 levels in the atmosphere, is one of the biggest challenges the world faces today. Being able to predict future climate trends is very important for planning ahead, making informed decisions, and creating better environmental policies. Traditional models often struggle to capture the complex, long-term relationships between different climate factors. In this paper, we introduce a graph-based neural network model that uses past climate data such as temperature, CO_2 levels, and other important information to make more accurate predictions. Our model builds on the strengths of advanced deep learning techniques like Long Short-Term Memory (LSTM) networks, which are good at learning from time-based data, and combines them with graph structures to better understand how different factors are connected over time and across regions. The results show that our method performs better than older models by finding hidden patterns and improving prediction accuracy. It also works well across different locations and can help where data is limited by learning from similar areas. This makes the model a powerful tool for scientists, researchers, and policymakers. As machine learning continues to grow, combining graph-based learning and LSTM models can help us build better systems for tracking and predicting climate changes. This can support smarter disaster planning, stronger climate action, and more global cooperation in protecting our planet.

Keywords: Climate Forecasting; Graph Neural Networks; LSTM; Temperature Prediction; CO_2 Emissions.

PAPER-ID-050

Strength And Durability Behaviour of Concrete in The Influence of Seawater and Waste Water: A Systematic Review

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Abstract

The growing scarcity of potable water poses a major challenge to concrete production, which consumes large volumes of freshwater. To ensure sustainability, it is crucial to adopt alternatives like treated wastewater, recycled water, and seawater that meet performance standards. This approach conserves drinking water, reduces environmental impact, and aligns with circular economy principles in the construction industry. This review evaluates the physicochemical properties of non-conventional water sources and their effects on concrete performance. From the literature, parameters such as pH, Total Dissolved Solids (TDS), chloride and sulphate concentrations, hardness, and turbidity are identified as critical influencers of strength and durability. Literature indicates that the 28-day compressive strength of concrete using treated wastewater ranges from 88% to 110% of that made with potable water, clustering mostly between 85–94%, especially when solids are kept below 2.5%. Seawater with high TDS (>30,000 mg/L) and chloride (15,000–19,000 mg/L) shows minimal effect on strength in unreinforced mixes but poses corrosion risks in reinforced concrete. Treated wastewater with TDS ≤ 2,500 mg/L and BOD ≤ 20 mg/L yields acceptable strength development within permissible limits mentioned by IS 456 (2000) and ACI 318 (2019) limits. Durability concerns arise from elevated chloride and sulphate, which can accelerate corrosion and sulphate attack. These effects can be reduced using sulphate-resisting cement and Supplementary Cementitious Materials (SCMs). Thus, with adequate treatment and quality control, alternative water sources especially in unreinforced applications offer a sustainable, technically viable option for concrete production.

Keywords: Sustainability; Non-conventional water sources; Concrete Strength; Durability.

PAPER-ID-051

Water Quality Check for Coral Growth Optimization: A Comparative Analysis Using Machine Learning Models

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Abstract

Coral reefs are among the most diverse and ecologically significant marine ecosystems, playing a crucial role in biodiversity preservation, coastal protection, and marine life sustenance. However, their survival is increasingly threatened by environmental stressors, including variations in water quality parameters such as pH, temperature, dissolved oxygen, and salinity. This study explores the application of machine learning techniques to classify water quality suitability for optimal coral growth. Utilizing a dataset of Indian coastal water quality, we examine key physicochemical parameters to determine their impact on coral ecosystem health. The research employs ten classification algorithms—Decision Tree, Random Forest, Support Vector Machine (SVM), Logistic Regression, K-Nearest Neighbors (KNN), Naïve Bayes, XGBoost, AdaBoost, Artificial Neural Networks (ANN), and Extra Trees—to predict water quality suitability for coral survival. Performance metrics such as accuracy, precision, recall, and F1-score are used to evaluate model efficacy. Among the tested algorithms, AdaBoost demonstrates superior predictive performance with an accuracy of 83%, precision of 90%, recall of 75%, and an F1-score of 78%, making it the most effective model for assessing water quality conditions conducive to coral growth. The study underscores the potential of machine learning in environmental monitoring and marine conservation. By automating the assessment of water quality parameters, this research provides a data-driven approach to support proactive coral reef management strategies. The findings contribute to the broader discourse on leveraging artificial intelligence for ecological sustainability, offering insights for marine biologists, conservationists, and policymakers. Future work may focus on integrating real-time water quality monitoring systems with advanced predictive models to enhance coral reef conservation efforts.

Keywords: Water Quality Monitoring; Coral Growth Optimization; Machine Learning Algorithms; Environmental Conservation; pH and Dissolved Oxygen.

PAPER-ID-052

Rethinking Waste Management: A Theoretical Framework and Actionable Propositions for AI and Machine Learning Integration

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Abstract

This study examines the transformative potential of Artificial Intelligence (AI) and Machine Learning (ML) in revolutionizing waste management practices. By developing a conceptual model grounded in Circular Economy principles, Diffusion of Innovation Theory, Resource-Based View, and Stakeholder Theory, it explores how AI can enhance efficiency and sustainability. The paper identifies critical factors influencing AI adoption and proposes hypotheses for future research, offering a roadmap for stakeholders to implement sustainable waste management systems.

Keywords: Waste Management; Sustainability; Artificial Intelligence (AI); Machine Learning (ML).

PAPER-ID-054

Building a Sustainable Circular Economy through Strategic HR Interventions: A Case Study of HPCL Biofuels Ltd

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Abstract

The shift to a sustainable circular economy necessitates technological and operational innovation. In addition, it also calls for strategic human resource initiatives that integrate environmental responsibility into the organisational culture. This paper studies a HPCL Biofuels Ltd. (HBL) plant located in Bihar as a case study to practically illustrate how a public sector industrial enterprise can practice the concept of a circular economy and be ESG compliant by conducting strategised human resource (HR) interventions. It demonstrates how the functions of HR extends beyond the internal company operations to community engagement through CSR projects and ESG compliance to finally attain the Sustainable Development Goals. The study has adopted a mixed-method approach. Primary observations and secondary material from HPCL Biofuels Ltd. is taken as the qualitative data for content analysis. Selected quantifiable data wherever available to support insights, are put up for descriptive statistical analysis. The study shows how the HR of HBL promotes practices that guarantee financial and legal accountability, while incorporating the 3Rs (Reduce, Reuse, and Recycle) into day-to-day operations. HR's responsibilities go beyond internal procedures to include ESG compliance and community involvement. This is further proven by the example of HBL wherein it is shown that circular economy models are intrinsically human oriented systems, and that in order to institutionalise sustainability throughout the organisational value chain, the HR strategies must be flexible, moral, and integrative.

Keywords: Circular economy; Sustainability; Environmental social and governance (ESG); Corporate social responsibility (CSR).

PAPER-ID-055

Production of Nano-biodiesel Blend Using Dairy Industry Waste

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Abstract

In the present situation impact on source of energy depletion, production of biodiesel attracts more priority in the field of alternative fuel due its renewability, more efficient fuel compared to conventional diesel fuel, Biodiesel is naturally known as Fatty Acid Methyl Ester (FAME), which is mostly extracted using vegetable oil. The non-edible oil are preferred upon the edible oils because of food verses fuel debate, even non edible oils require cultivation and use of agricultural land even causes concern and may get to a worried situation like soil degradation and food security. Hence it is important that production of biodiesel from non-edible oil and edible oil, should be replaced with some other sources, thus industrial wastes, animal wastes, agricultural wastes, etc have opened up forum for the intellectual minds to find the ways for alternative source for biodiesel. Past research have been done on the animal fats, fish fats, etc, along with these the use of wasted lipids from diary industry has also opened a new avenue for study of competitive and less in cost biodiesel, in diary industry machines and transport systems are used for storing, packing, transporting the dairy products, which are washed frequently with abundant water, this sludge contains organic matters like lipids, carbohydrates etc, they are called as Dairy Waste Scum (DWS), with small efforts we can extract the fatty acids and convert into oil, which further in trans-esterification process biodiesel can be achieved known as Diary Scum Oil (DSO) biodiesel, which give par results compared to conventional diesel. With this further more to increase the properties of DSO- biodiesel, it can be blended with Carbon Black (CB) nano additives, prepared blend named Dairy Scum Oil Carbon Black (DSOCB) nano biodiesel which are compared to ASTM standards and found suitable for engine fuel as an alternative fuel.

Keywords: Alternative Fuel; Diesel; Biodiesel; Dairy scum waste; Nano additive.

PAPER-ID-056

Eco-Friendly Recovery of Gold from Printed Circuit Boards Using Cyanide-Producing *Chromobacterium Violaceum*

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Abstract

The growing accumulation of e-wastes has become a new urban mining source of precious metals including gold. Pyrometallurgical extraction and hydrometallurgical extraction with cyanide are the traditional routes for recovering gold that are energy-intensive with associated serious health hazards. Bioleaching is an environment friendly and sustainable method of recovering metals from solid waste items by using microorganisms' metabolism abilities. The present research investigates the targeted extraction of gold from crushed printed circuit boards (PCBs) utilizing *Chromobacterium violaceum* (*C. violaceum*), a facultative anaerobic known for its ability to produce cyanide. *C. violaceum* was cultivated pursuant to monitored conditions to enhance gold solubilisation. A thorough analysis of the effects of factors on gold recovery, e.g., bacterial growth kinetics, pH (1.5–3.0), redox potential, and colonial morphology, was conducted. The optimal pH range for the living organisms' bioleaching capability was 2.0–3.0, while the optimum temperature range was 30–35 °C. The extent of gold was greatly enhanced by the cyanide compound that bacteria created during fermentation. The PCB specimens were characterized using X-ray diffraction (XRD), scanning electron microscopy with energy dispersive spectroscopy (SEM-EDS), and inductively coupled plasma optical emission spectroscopy (ICP-OES) at various stages of extraction in order to assess the efficacy of extraction. This approach validated the targeted mobilization of gold and notable changes in the surface structure of the treated PCBs. The findings confirmed *C. violaceum* as a potent microbe for gold extraction, highlighting the potential of bioleaching as an environment friendly metallurgical method of gold extraction. This technique advances equitable growth goals by lowering harmful emissions and improving circular economy practices for processing e-wastes.

Keywords: Bioleaching; Gold Recovery; E-waste; PCB; Cyanogenic Bacteria.

PAPER-ID-059

Dyeing Cotton Fabrics by Waste Flowers of Palash (*Butea Monosperma*l.) And Marigold (*Tagetes Erecta*)

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Abstract

Dyeing is a process of applying coloring matter directly on fiber or fabric with or without any additives. Natural dyes were used only for coloring of textiles from ancient times till the nineteenth century. Natural dyes are derived from natural resources. Coloring materials obtained from natural resources of plant were used for coloration of various textile materials. Now a day a growing interest in the revival of natural dyes has been manifested to replace the synthetic dye. This interest is a result of worldwide movement to protect the environment for discriminate exploration and pollution by industries. In the present investigation waste flowers of of palash (*Butea monosperma*L.) and marigold (*Tagetes erecta*) were used for extracting the dye and examined its possible usage in textile coloration. The effect of mordents employed in the dyeing with the dyes were also studied. The waste flowers of *Butea monosperma*, naturally lying in the forest area, were collected from Dorodih forest area in purulia district. And the used flowers of marigold were collected from the temples. Different mordants were used for understanding of colour production and various fastness properties. Extraction and dyeing conditions of natural dyes from waste flowers of *Butea monosperma* and marigold (*Tagetes erecta*) have been optimized in neutral medium i.e. water and various beautiful shades developed on cotton fabrics using different chemical mordants are being described in this article.

Key words: *Butea monosperma*; Natural dyes; Extraction; Cotton fabric; Chemical mordants.

PAPER-ID-060

Electrocoagulation vs. Hydrodynamic Cavitation: A Comparative Study on Rice Mill Effluent

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Abstract

Rice mill effluent (RME) is characterized by high turbidity, organic load, and unstable pH, demanding efficient treatment strategies. In this study, electrocoagulation (EC) and hydrodynamic cavitation (HC) were evaluated as standalone processes for RME treatment. The initial effluent pH ranged between 6.2 and 6.8. Post-treatment, EC gradually stabilized the pH to near-neutral levels (7.0–7.2), while HC provided a faster adjustment, reaching 6.8–7.0. Turbidity levels in raw effluent exceeded 400 NTU. EC demonstrated superior turbidity removal, achieving 90–95% reduction within 20 minutes and lowering turbidity below 30 NTU. HC also proved effective, with 85–90% reduction in 30 minutes, decreasing turbidity to <50 NTU. The chemical oxygen demand (COD) of the untreated effluent ranged from 3500 to 4500 mg/L. EC exhibited progressive pollutant removal, reducing COD by 70–75% after 90 minutes, reaching final levels of 650–850 mg/L through the formation of metal hydroxide flocs. HC, in contrast, enabled faster treatment, removing 40–45% COD within 20 minutes and achieving 60–65% reduction in 40 minutes due to intense cavity collapse and radical generation. Overall, both methods proved effective, with EC favoring higher pollutant removal efficiency and HC providing rapid treatment. These findings highlight the potential of integrating EC and HC for sustainable RME management.

Keywords: Rice mill effluent; Electrocoagulation; Hydrodynamic cavitation; COD reduction; Turbidity removal; Wastewater treatment.

PAPER-ID-065

Characterization of Silver Nanoparticle and Slag-Reinforced Jute/Kenaf/Glass–Epoxy Composites for Structural Applications

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Abstract

In the present era, industrial waste slag generated from petrochemical and refinery plants, thermal power stations, refractory units, and ferrous or non-ferrous industries poses a significant challenge to society. Among these, blast furnace slag (BFS) is a major category of slag produced in steel industries and is known to cause irritation of the lungs, skin, and eyes. This work has focused on enhancing the utilization of waste materials that suppress environmental pollution. Meanwhile, the inward potential of these waste materials can be converted into useful and sustainable components/products. Over the last few decades, there has been growing interest in the development of epoxy-based composites, mainly due to their wide availability, low cost, lightweight nature, environmental friendliness, and sustainability. In this study, epoxy-based composite laminates were fabricated using jute/kenaf/glass fiber in various stacking sequences and fiber orientations, along with BFS (excluding zero CaO, following chemical treatment) and silver nanoparticles (AgNPs). These composite laminates are proposed as an alternative to conventional structural materials, offering the added benefit of antimicrobial properties imparted by AgNPs. Furthermore, mechanical, microhardness, antimicrobial, and corrosion properties will be investigated.

Keywords: Blast furnace slag (BFS); Silver nanoparticles; Fiber; Epoxy resin; Mechanical properties.

PAPER-ID-069

Evaluating the Implementation of Swachh Bharat Abhiyan (SBA): A Comparative Review of Pan-India and West Bengal Outcomes Aligned with SDG 6

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Abstract

The Swachh Bharat Abhiyan (SBA), launched in 2014, is India's flagship national mission to eliminate open defecation, improve solid and liquid waste management, and promote hygiene practices. Closely aligned with Sustainable Development Goal (SDG) 6 – Clean Water and Sanitation, SBA also contributes to SDG 3 (Good Health and Well-being) and SDG 11 (Sustainable Cities and Communities). Despite nationwide progress, regional disparities in implementation and outcomes remain underexplored.

This study aims to conceptually model and evaluate the breadth and depth of SBA implementation, comparing Pan-India performance with that of West Bengal, to identify how sanitation infrastructure, behavioural change, and sustainability outcomes vary across regions. The objective is to trace the evolution of outcomes before and after SBA, highlighting the program's measurable benefits and limitations within different governance and cultural contexts.

A systematic review methodology was adopted, drawing on peer-reviewed journal articles, policy reports, and government evaluations published between 2014 and 2025. Inclusion criteria required studies to focus on SBA's implementation, outcomes, or behavioural sustainability. Sources were extracted from Scopus and PubMed to ensure comprehensive national and regional coverage.

Findings indicate that while SBA has significantly increased sanitation infrastructure coverage and open defecation-free (ODF) declarations across India, West Bengal's experience reflects challenges in long-term behavioural adherence, community-led waste management, and ODF sustainability. The comparison reveals critical insights into the gap between infrastructure creation and behavioural transformation.

This paper is novel in offering a dual-scale evaluation model, linking national sanitation policy with state-specific implementation patterns. It also contributes a framework for SDG-aligned impact assessment, highlighting the need for context-driven strategies to ensure equitable and sustainable sanitation outcomes across India.

Keywords: Swachh Bharat Abhiyan; Sanitation; Sustainable Development Goals (SDG 6); Behavioural Change; Systematic Review.

PAPER-ID-070

Bridging Foundations and Practice: Analytical Techniques and Real-Time Insights for Predictive Energy Management in Smart Cities

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Abstract

The fast-paced growth of smart cities globally demands innovative, data-intensive energy management practices that are sustainable, efficient, and resilient. In this paper, an integrated predictive energy management framework is introduced that brings together seminal research with real-world application via disparate real-time data streams, most notably weather data and social media analytics. Based on a thorough systematic review of more than 40 seminal studies and new real-time data gathered in Lucknow, India, the research assesses a range of analytical methods such as traditional statistical methods, varied machine learning methods, and advanced deep learning models. The difficulties inherent in urban data, i.e., missing values, noise, and privacy issues, are handled with caution for ensuring applicability and robustness. Our empirical examination demonstrates that ensemble machine learning models coupled with sequence-based deep architectures outperform regular statistical models by as much as an 18 - 20% improvement in the accuracy of hourly urban energy consumption predictions. Additionally, the article presents practical considerations for implementing such prediction models in smart city infrastructures, such as data collection through APIs (e.g., NOAA for weather, Twitter for social media), real-time processing, and respect for ethical usage of data. Through a comparative assessment and actionable recommendations, this work contributes to the creation of scalable, interpretable, and privacy-sensitive predictive energy management systems. Finally, the suggested framework enables policymakers and city planners to make informed choices that are based on maximized energy use, which goes a long way in realizing smart and sustainable cities.

Keywords: Predictive Energy Management; Smart Cities; Real-Time Data; Machine Learning; Deep Learning; Weather Data; Social Media Analytics.

PAPER-ID-072

Sustainable Recovery of Nanocellulose from Landfill-Derived Waste: Advancing Circular Economy and Resource Valorization

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Abstract

Every year, millions of wastes are being generated as a result of development and civilization which being dumped in the landfill. These landfill wastes are a mixture of papers, cardboards, batteries, electronics, textile wastes, construction debris, pesticides, agricultural by-products, industrial wastes, vegetable wates, etc. In contrast to western countries, most of the solid waste dumped in the landfills of Asian cities contains a higher proportion of organic matter, along with significant amounts of dirt and dust that accounts 70-80% of the total waste composition. Utilization of these landfill organic wastes for the development of value-added products can be sustainable approach towards the circular economy. Nanocellulose (NC), a natural material whose at least one dimension must be in nanoscale, derived from cellulose exhibits exceptional properties like low density, high mechanical strength, high surface area, and biodegradability due to which enabling its emerging application in different sectors inclusion of water & wastewater purification, sustainable packaging, cosmetics, biomedical fields. This paper represents a detailed review on the sustainable transformation of landfill-derived waste into nanocellulose using environmentally benign process which introduces the application of enzymatic hydrolysis, mechanical treatments like ultrasonication instead of using different chemicals. This review also focuses on the design of suitable optimization techniques for resource recovery of residual components like lignin and hemicellulose for the efficient conversion to value-added products including biofuels and other valuable chemicals. This integrated approach not only facilitates material recovery but also alleviates landfill burden, reduces greenhouse gas emissions, and advances circular economy principles. The conversion of municipal waste into high performance, sustainable nanocellulose exemplifies the potential of innovative waste valorization strategies.

Keywords: Nanocellulose; Circular economy; Waste-to-resource; Sustainable conversion; Landfill waste.

PAPER-ID-077

Household Solid Waste Management Practices and its Impact on Environment and Health: A Comparative Study from Mumbai and Pune

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Abstract

Solid waste management poses persistent challenge in urban cities, with significant implications on public health and environment. This study presents a comparative analysis of household waste management practices in Mumbai and Pune, two major metropolitan cities in Maharashtra, emphasizing the role of socioeconomic factors. By means of primary data collected through structured questionnaires, the research examines arrays of spending habits, waste generation, segregation, disposal methods, and awareness levels across different income groups and residential types. Findings from this paper show unambiguous difference in household spending habits (extensive online buying pattern) between low income and high income group people. Furthermore, inappropriate disposal lead to localized environmental deterioration, health risks etc. particularly for vulnerable groups. The study emphasizes the need for inclusive, community-based waste management strategies to tackle the issue; also there is a need to address the behavioural issues among people of different income groups. Recommendations include upgrading infrastructure by developing Material Recovery Facilities (MRFs) in each zone for dry waste sorting. Also Decentralized Waste Processing units to be set up at community level so that it will reduce the load on centralized landfills by processing waste near the source. Support startups in Recycling. Upcycling and Composting.

Keywords: Solid Waste Management; Socioeconomic factors.

PAPER-ID-080

Copper Nanoparticles in Heavy Metal Remediation

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Abstract

Copper nanoparticles are minute materials that are known to have high electrical conductivity and optical properties. It has been found to play a catalytic role in the removal of heavy metals such as Chromium (Cr), Mercury (Hg), and Cadmium (Cd) from the ecosystem. It can be synthesized by both physical and chemical processes, which require a reducing agent for its functioning. In this review article, the remediation potential of copper nanoparticles on various heavy metals in both terrestrial and aquatic ecosystems is analysed. The issues and challenges associated with the remediation of heavy metals using copper nanoparticles have also been discussed. In the analysis, it has been found that copper nanoparticle-mediated remediation has good potential in dealing with heavy metal toxicity in the ecosystem.

Keywords: Nanoparticle synthesis; Heavy metals; Remediation; Ecosystem.

PAPER-ID-084

AI-Driven Drone–Sensor Framework Enabling Precision Agriculture and Waste Minimization

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Abstract

Agricultural waste is still a major problem for maintaining food sustainability and security, particularly in rural areas with limited resources. To solve this problem, precision agriculture—made possible by sophisticated technologies like drones and distributed sensor networks—offers revolutionary possibilities. To transform on-field decision-making, this project combines an Aerial Drone Unit and DEW Node Sensor Network with AI-driven analytics. Accurate crop recommendation, crop weed classification, pest detection, early disease identification are made possible by the drone's real-time RGB, multispectral, and infrared (IR) imaging. Temperature, pH, moisture, and nutrient levels are all simultaneously monitored by soil-embedded DEW nodes, enabling accurate, data-supported crop suggestions and input management.

The technology minimizes chemical-related waste by preventing yield loss and reducing needless pesticide use by identifying crop illnesses and pests in their early stages. By ensuring targeted pesticide administration, weed classification reduces ecological damage and soil degradation. AI-based crop advice maximizes productivity and avoids overproduction or inappropriate crop choices, two main waste contributors, by coordinating planting methods with real-time soil and climate data. Integrated livestock monitoring also improves animal health surveillance by lowering feed waste, stopping the spread of disease, and increasing animal product productivity. Through an easy-to-use interface, this intelligent, automated ecosystem enables even farmers who are not tech-savvy while lowering manual labour and increasing resource efficiency. A low-waste, high-efficiency agricultural future is made possible by the solution, which promotes food security, sustainable practices, resilient rural development, and poverty reduction.

Keywords: Agricultural waste; Aerial Drone; DEW Node Sensor Network; RGB; Infrared imaging.

PAPER-ID-087

Global Research Trends on the Degradation of Recycled Composites: A Bibliometric Perspective

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Abstract

This study presents a bibliometric analysis of global research trends on the degradation of recycled composites, offering a comprehensive perspective on publication patterns, thematic evolution, and emerging research gaps. Using the Scopus database and a targeted search strategy, 368 English-language journal articles published between 2010 and 2025 were analyzed. Visualization was conducted with VOSviewer 1.6.20 and Biblioshiny 2.0, and rankings were assigned to the most significant documents, authors, sources, organizations, and countries based on total citations, number of publications, average citations, and total link strength. Co-occurrence mapping of author keywords, index keywords, and high-relevance text terms was performed with thresholds to capture both dominant themes and niche but impactful topics.

Results show that keywords related to recycling-notably recycling and plastic recycling-are central thematic drivers, closely linked with mechanical properties such as tensile strength and impact strength. Degradation and weathering studies are well-represented, with recycled polypropylene emerging as the most frequently investigated material. Analytical techniques including scanning electron microscopy, thermogravimetric analysis, and Fourier-transform infrared spectroscopy are among the most widely cited methods for evaluating degradation-related changes. Despite this progress, gaps persist in multi-factor degradation modelling, synergistic aging studies, and nanocomposite strategies for enhanced durability. Limited research addresses the environmental toxicity of degradation products or the potential of additive manufacturing in recycled composite applications. The findings highlight a mature yet evolving research field and provide a data-driven foundation to guide future work toward improved performance and sustainable life-cycle outcomes for recycled composite materials.

Keywords: Recycled composites; Degradation; Bibliometric analysis; Mechanical properties.

PAPER-ID-088

Sustainable Upcycling of Scrap Metal Sheets via Hydroforming for Circular Manufacturing

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Abstract

The escalating generation of ferrous and non-ferrous sheet metal waste from automotive, construction, and manufacturing sectors necessitates sustainable valorization pathways. This study investigates the application of hydroforming—a high-pressure fluid-assisted forming process—for upcycling heterogeneous scrap metal sheets into high-value, lightweight, and structurally resilient components. The research encompasses material recovery and preprocessing protocols (including de-coating, surface cleaning, and thickness calibration) to mitigate contamination and alloy inconsistency. Experimental trials optimize hydroforming process parameters—fluid pressure profiles, blank holding forces, and strain rates—tailored to recycled sheet properties to ensure mechanical integrity and geometrical precision. Performance metrics include yield strength retention, formability index, springback minimization, and dimensional tolerance compliance. A comparative life cycle assessment (LCA) quantifies embodied energy savings and greenhouse gas (GHG) reduction relative to fabrication from virgin feedstocks. Preliminary findings indicate that integrating scrap metal hydroforming into municipal and industrial waste management streams supports closed-loop material cycles, decreases landfill dependency, and reduces primary resource extraction. The work demonstrates a technically feasible approach that merges advanced forming technology with resource efficiency strategies, enabling scalable implementation within circular manufacturing frameworks.

Keywords: Hydroforming; Scrap metal upcycling; High-pressure forming; LCA; Circular economy; Sustainable manufacturing.

PAPER-ID-091

Variation of Aerosols and LST Around Landfill Sites in Delhi

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Abstract

Delhi's two major environmental issues at present are poor air quality during winters and overflowing landfill sites. These two environmental problems are dealt in detail and been discussed under different government departments. The other associated problem of urbanized city are rising temperatures. In this study, the effect of landfill sites on air quality and urban temperature is discussed. Three landfill sites of Delhi i.e. Bhalswa, Ghazipur and Okhla are studied for air quality using Aerosol Optical Depth (AOD) and urban temperature via Land Surface Temperature (LST) estimation using multi-ring buffer analysis. The analysis during highest average AQI (374) month of 2024 i.e. November as per PIB was done. The sub analysis of period with AQI > 400 (13-23 Nov., 2024) showed that AOD at landfill sites estimated using MODIS 1 km MCD19A2 product varied from 0.9 to 3.8 indicating that higher pollution exists at landfill sites. The LST-MODIS estimation showed that LST at landfill sites are higher as compared to different land use in vicinity of the landfill sites. The ambient temperature in 5 km^2 buffer area of landfill sites was also analysed using CAAQM stations available within 3 km radius.

Keywords: Landfill; AOD; LST; Climate Change.

PAPER-ID-094

Sustainable Papercrete Bricks from Demolished Construction Waste to Net Zero

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Abstract

This study explores the potential of papercrete as a sustainable alternative to conventional bricks by utilizing paper pulp-cement composites (extracted from demolished construction waste) and innovative pathway toward net-zero construction practices. Experimental results demonstrate that papercrete bricks, produced from recycled paper pulp and cement, exhibit compressive strength suitable for non-load bearing walls. Although the water absorption capacity exceeded the recommended 20%, rendering them unsuitable for waterlogged or external applications, the use of waterproof coatings such as Geobond or silicon-based materials enables effective utilization as partition walls. Compared to conventional concrete cubes, papercrete bricks weigh nearly one-fourth less, significantly reducing the dead load of buildings and enhancing safety in earthquake-prone regions. Their high fire resistance, superior thermal insulation (R-value 2–3 per inch), and sound-absorbing properties provide long-term environmental and economic benefits. Furthermore, the reuse of demolished construction waste and paper pulp minimizes landfill pressure, lowers pollution, and reduces overall construction costs by 20%–50%. Test observations confirm high energy absorption capacity, resistance to brittle failure, and reduced labor costs. By integrating waste management with green building practices, papercrete bricks from demolished construction waste emerge as an economical, lightweight, and eco-efficient alternative, advancing the vision of net-zero and sustainable construction.

Keywords: Sustainable Development; Waste to Utilization.

PAPER-ID-095

Autonomous Vision-Based Waste Collection System: A Simulation Framework for Smart Urban Management

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Abstract

Urban waste management system faces an increase in demand in modern cities. This paper presents a simulation-based software for developing an autonomous waste collection vehicle utilizing line sensors and encoders. The system uses software to manage line routes, load handling, and efficient collection strategies. The framework used here is a closed-loop navigation system where the autonomous vehicle travels on a predefined path using vision-based guidance. The system has several strategically positioned collection stations, which help in gathering the waste. Advanced load monitoring is being used for intelligent routing decisions when a predetermined capacity threshold is reached, and therefore starts automated diversion towards the designated disposal area(s). The vehicle employs bidirectional path optimization to quickly resume collection, thus cutting time and energy use. The simulation environment uses artificial data sets for algorithm testing and thus eliminates hardware dependencies while maintaining consistent performance. Core functions include autonomous line detection, collection point recognition, and disposal facility identification through computer vision processing. The framework prioritizes accessibility through web-based deployment and open-source integration and thus helping in rapid prototyping and cost-effective development. The experimental results help us in understanding the effectiveness of vision-driven autonomous navigation for waste management applications. The system demonstrates autonomous collection protocols, dynamic load balancing, and route optimization. This research lays the groundwork for autonomous waste collection in smart cities, aiding smart urban infrastructure development.

Keywords: Autonomous Navigation; Computer Vision; Smart Cities; Waste Management.

PAPER-ID-096

Sustainable Utilization of Spent Battery Electrode Materials for Wastewater Treatment in Textile Industry

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Abstract

India is the third-largest exporter of clothing and textiles in the world, contributing 2% of its GDP. The textile industries are experiencing notable growth, which is accompanied by a rise in the discharge of wastewater from these sectors. The wastewater contains hazardous substances such chemicals, pigments, dyes, and suspended particles, which are threat to the aquatic flora and fauna. To tackle this problem, the photocatalytic degradation process is utilized to breakdown dyes in the wastewater from the textile industries, the photocatalysts that are generally used contains carbon or transition elements like titanium, cobalt, iron, zinc, etc.

Another concerning issue is the recycling of the spent battery electrodes, due to increase in demand for electronic gadgets and electric vehicles. The spent battery electrodes are usually commercially used cathodes/anodes like lithium nickel manganese cobalt oxide ($LiNiMnCoO_2$, NMC), lithium cobalt oxide ($LiCoO_2$), lithium iron phosphate ($LiFePO_4$ or LFP), graphite, etc. There are several ways to address both the issues independently. However, we propose a solution where one pollutant can be used to degrade the other. In this work, we intend to use the spent battery materials and use them as a photocatalysts. The spent battery electrode materials are recovered and used as a photocatalyst. These photocatalyst helps in degrading the dyes like methyl orange, methylene blue, Congo red, rhodamine B, and others, released from the textile industries. The primary benefit of this solution is that it addresses both the issues simultaneously while promoting sustainability and reducing the overall cost.

Keywords: Wastewater; Spent battery electrode material; Photocatalysis; Recycling.

PAPER-ID-097

Waste to Wellness: The Role of Immunomodulatory Potential of Food By-Products

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Abstract

Food waste and by-products, traditionally considered agricultural and industrial residues, are increasingly recognized as sustainable sources of bioactive compounds with potential immunomodulatory properties. Growing evidence suggests that peels, seeds, pomace, and husks from fruits, vegetables, cereals, and seafood contain high concentrations of polyphenols, flavonoids, carotenoids, dietary fibers, and bioactive polysaccharides that can modulate immune function. Transforming these undervalued resources into functional ingredients addresses ecological concerns while opening new avenues for immune health. This review aims to examine the immunomodulatory potential of food by-products, highlight key bioactive constituents, and explore their applications in functional foods and nutraceuticals. This secondary review evaluated in vitro, in vivo, and clinical studies on food by-product extracts, emphasizing cytokines, macrophages, antioxidants, and gut microbiota. Findings indicate that bioactive compounds exert antioxidant, anti-inflammatory, antimicrobial, and prebiotic effects, thereby influencing both innate and adaptive immune responses. For example, citrus peels and pomegranate rind are rich in flavonoids and ellagitannins that suppress pro-inflammatory cytokines, while grape seed proanthocyanidins enhance T-cell activity and macrophage function. Cereal bran-derived arabinoxylans and β-glucans stimulate gut-associated lymphoid tissue and improve mucosal immunity. Similarly, shrimp shell-derived chitosan has demonstrated phagocytosis-enhancing and antimicrobial properties. Evidence supports their role in reducing infection risks and chronic inflammation. The valorization of food waste into functional foods and nutraceuticals therefore represents a dual opportunity—supporting sustainable waste management and advancing immune health. Further research on bioavailability, dose optimization, and clinical efficacy is warranted to translate these findings into dietary interventions and therapeutic applications.

Keywords- Food waste; By-products; Bioactive compounds; Immunomodulatory properties; Nutraceuticals.

PAPER-ID-100

Organic Compost of Forest Waste Materials (Shorea Robusta) for Sustainable Agriculture in India by Amrit Krishi Farming model

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Abstract

With a focus on escalation in productivity, Indian agriculture has distorted from being a food deficient to food sufficient nation. However, a high growth in input cost have outweighed equivalent growth in the value of output, which unfavourably impacting farmer's income. Beside these, there is a decrease in organic carbon content as well as macro and micro nutrients in most Indian soil. Despite accomplishing food security, India is still slugging with the issue of nutritional security and growing cases of burnt crop waste which are affecting serious environmental thread.

Worldwide, forest or agricultural practices are responsible for one-third of the universal green-house gas emission. Though, regenerative forest or agriculture model promotes the kind of practices that are reducing green-house gas emission by assembly usage of organic waste to produce manure enriching soil, also promoting carbon-sequestration and making microbiome of soil rich in organic matter.

A symbiotic-sustainable relationship is being envisioned between nature, framers and consumers to create a win-win situation for all. So, "Amrit Krishi" is one such innovative and seamless model of farming directed generally towards small, poor and marginal farmers.

The Production of Amrit Soil from forest waste - Shorea robusta offers a sustainable rejoinder to nutrient management in organic farming while simultaneously addressing waste management challenges. By harnessing the potential of advantageous microorganisms (Azotobacter and Rhizobium), it contributes to on – line analyzation & investigation, soil health improvement, chemical free finished goods & organic farming.

Keywords: Forest waste; Shorea robusta; Azotobacter & Rhizobium; Cost -effective production.

PAPER-ID-101

The Ecology-Economy Nexus: Waste Water Resource Recovery and Risks in East Kolkata and Konnagar-Hindmotor Wetlands, West Bengal, India

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Abstract

Wetlands are frequently referred to as the ecosystem's "natural kidneys". Geographically Isolated Wetlands (GIWs) and Ramsar-designated 'Wetlands of International Importance' both play a major role in maintaining ecosystem stability and biodiversity. The East Kolkata Wetlands (EKW) and the Konnagar-Hindmotor Wetlands (KHW), serves as a model for resource recovery. The stormwater and sewage water from the city of Kolkata are sent to fishponds, or '*bheris*' where wastewater from the city of Kolkata is treated naturally. The EKW and KHW provides environmental security to the local stakeholders by providing essential ecological services. The wetlands provide treated wastewater for horticulture and agriculture in addition to sewage-fed aquaculture. Unsustainable urbanization is presently posing a serious threat to the EKW and KHW wetlands wherein these wetlands are rapidly infilled thereby resulting in permanent environmental harm. Thus, the paper aims to find out the mechanism of city's stormwater and sewage water being converted into wealth i.e. sewage fed aquaculture providing the city with the fresh supply of fishes and vegetables without incurring additional expenditures on waste water management. The paper also aims to analyze the impacts of infilling of the wetlands on the ecological services.

In-depth interviews comprising of 250 stakeholders, RAWES, analysis through satellite imageries revealed that the city of Kolkata and its adjoining areas are facing incidences of increased waterlogging, flood-like conditions, and extreme strain on current water resources. Thus, the region is experiencing increased ecological stress as a result of these changes along with the widespread destruction of floral and faunal habitats. Thus, the study concludes that wetlands must be conserved and managed sustainably for maintaining environmental and socio-economic stability.

Keywords: East Kolkata Wetlands; Sewage Water; Wetlands Infilling; Ecological Services.

PAPER-ID-103

Synthesis of Silver Doped Zinc Oxide / Magnesium Oxide Nanoparticles and Its Adsorptive Studies on Removal of Congo Red Dye

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Abstract

The present study, aims to exploit the experimental determination of biosorptive characteristics of synthesized silver doped zinc oxide/ magnesium oxide nanoparticles (Ag doped ZnO/MgO-Np's) with leaf extract. Synthesized Ag doped ZnO-/MgONp's were characterized by SEM, XRD FTIR and EDX analysis. The resultant nanoparticle size obtained is 122nm. The process variables such as Agitation time, Initial concentration of CR dye, pH, Dosage of Ag doped ZnO/MgO-Np's and Temperature were performed and compared by using response surface methodology (RSM). At the optimized parameter conditions, the dye adsorption was studied from Isotherms, Kinetics and Thermodynamics, respectively. At the optimized conditions, maximum removal (94.3%) of CR dye obtained. It was found that the Freundlich-isotherm, pseudo second order kinetics fitted the data better as compared to other isotherm and kinetic models. The results of thermodynamic studies exhibits the exothermic nature, thermodynamically feasible nature of adsorption.

Keywords: Congo red; Ag doped ZnO/MgO-Np's; Isotherms; Kinetics; Thermodynamics.

PAPER-ID-105

Synergistic Pozzolanic Interaction of Fly Ash and Rice Husk Ash in Enhancement of Mechanical and Durability Performance of Cementitious Composites

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Abstract

This study investigates the synergetic effect of combining fly ash and rice husk ash in concrete, focusing on the enhancement of mechanical and durability properties compared to conventional Ordinary Portland Cement (OPC) concrete. The research compares three mixes: OPC concrete, Fly Ash Concrete (FAC), and Rice Husk Ash + Fly Ash Concrete (RHFAC), with specific emphasis on compressive strength, split tensile strength, flexural strength, chloride permeability, and water absorption. The incorporation of fly ash improves particle packing, pozzolanic reactivity, and long-term strength gain, while rice husk ash contributes ultra-fine silica that further refines pore structure and improves matrix densification. The combined use in RHFAC demonstrates a true synergetic effect, as evidenced by higher strength values and improved durability indicators compared to FAC alone. Test results reveal that RHFAC exhibits approximately 18% higher 28-day compressive strength than OPC concrete, and 7% higher than FAC. Split tensile and flexural strengths follow a similar trend, indicating improved crack resistance. Rapid Chloride Permeability Tests (RCPT) show a significant reduction in charge passed—39% lower in RHFAC compared to OPC—indicating superior resistance to chloride ingress. Water absorption is also reduced by 25% in RHFAC relative to OPC, enhancing its durability in aggressive environments. The integrated effect of industrial waste (fly ash) and agricultural waste (rice husk ash) by-products not only improves the engineering performance of concrete but also contributes to sustainability goals by reducing cement usage, promoting waste valorization, and extending service life. This study underscores the potential of RHFAC as a high-performance, durable, and eco-efficient construction material.

Keywords: Synergetic effect; Fly ash; Rice-husk ash; Mechanical; Durability; Sustainable Concrete.

PAPER-ID-107

A Comparative Study of Soil Characteristics in Residential, Industrial, Forest, and Sensitive Areas: Implications for Environmental Management

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Abstract

In order to evaluate the consequences for environmental management, this study compares the properties of soil in four different land-use zones: residential, industrial, forest, and environmentally sensitive areas. Key physicochemical characteristics, such as pH and Particle size distribution (PSD) were examined in soil samples that were taken from typical locations within each zone. The results demonstrate notable differences in soil quality, with forest and sensitive zones displaying better soil profiles with higher organic content and balanced nutrient composition, while industrial regions displayed higher pollution levels and lower fertility. Due to construction operations and urban runoff, residential areas showed considerable soil degradation. The study emphasizes the significance of targeted soil conservation measures that are adapted to the unique characteristics of each area and land-use planning. For legislators and environmental planners seeking to advance sustainable land management and lessen soil deterioration in urban and peri-urban areas, the findings offer insightful information. A total 13 nos. of samples were collected from four different land-use zones: residential, industrial, forest, and environmentally sensitive areas. This soil is to some extent alkaline (pH 7.72–8.75) and signs of calcareous deposit. Characteristics of PSD Uncertainty in Industrial area varied from 0.26 to 0.83 with an average 0.60% (which is <1%), in Horticulture area from 0.19 to 1.09 with an average 0.64% (which is <1%), in Sensitive area was 0.29 (which is <1%), in Forest area from 0.50 to 2.46 with an average 1.21% (which is <2%) and in Residential area from 0.22 to 0.67 with an average 0.51% (which is <1%).

Keywords: Soil characteristics; Contamination; Environmental sustainability.

PAPER-ID-108

Sustainable Waste Management and Resource Valorization Strategies for Kolkata Leather Complex

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Abstract

The Kolkata Leather Complex (KLC), is one of the India's largest leather production facilities, it faces critical environmental challenges due to the generation of huge volumes of hazardous liquid and solid wastes during leather production process. Each tonne of rawhide produces 600–870 kg of solid waste and 30–35 m^3 of wastewater, comprising of high pollutant loads of BOD (2000–3500 mg/L), COD (4000–8000 mg/L), TSS (1000–2500 mg/L), and chromium (100–300 mg/L), all of which are in excess of permissible limits. The study thus aims to investigate the impacts on soil, water, and public health while presenting an innovative circular economy-based approach. The study also quantifies pollutants like sodium sulphide, sodium formate, ammonium sulphate, and chrome sulphate. The study employs a mixed methods approach combining field surveys, laboratory simulations, and technological modeling. Waste segregation and characterization are followed by valorization methodology, such as enzyme-based hydrolysis for recovery of protein and collagen (70–80% efficiency) and alkaline methods for chromium recovery (90–95% efficiency). IoT-based sensors monitor the real-time parameters including pH, BOD, and chromium levels, creating a data-driven mechanism for compliance and process optimization. Activated carbon derived from leather waste provide an alternative cost-effective filtration, enabling alignment with central pollution control board (CPCB) guidelines and SME capacities. The integrated recovery technologies led to the reduction of hazardous discharges by 70–90% and solid waste by 40–50%, while producing value-added products like biofertilizers, animal feed, and reusable chemicals.

Keywords: Leather; Waste; BOD; Chemicals.

PAPER-ID-109

Sustainable Recycling with AI: Improving the Quality and Value of Recycled Plastics

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Abstract

Through the precise identification of polymer kinds from FTIR spectra and the detection of visual contamination in waste streams, this work creates and assesses a two-track AI pipeline to raise the market value of recovered plastics. Chemometrics, classical machine learning, and deep learning (1D-CNN) would be compared for spectral polymer identification using FTIR libraries and curated datasets. Industrial and the waste image datasets are used to train research-grade instance segmentation models using Mask R-CNN or Detectron2, as well as rapid object detectors utilizing YOLOv8 for vision-based contamination identification. Sorting accuracy would be increased to grade-wise tonnage and market prices in order to show the economic benefit. This would result in bootstrapped estimations of revenue uplift under realistic purity and error scenarios to ensure sustainable recycling. In order to facilitate practical adoption, explainability evaluations are included, along with spectra, vision, and deployment practicality. These findings emphasize the significance of ongoing technological advancements supported by robust regulation and stakeholder cooperation in order to decrease plastic waste and accelerate the transition to a sustainable circular economy.

Keywords: Recycled Plastics; FTIR Spectra; Polymer Identification; Contamination Detection; Sustainable recycling.

PAPER-ID-110

Recycling and Restoring Materials in the Electronic Industry

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Abstract

The electronic industry generates a significant amount of waste, commonly referred to as electronic waste or e-waste. This waste includes discarded devices like smartphones, televisions, computers, keyboards, switches, casings, wires, batteries and several types of defective laboratory components. Recycling in the electronic industry is an essential practice for recovering valuable materials from the e-waste generated which simultaneously helps in reducing environmental effects. E-waste contains a variety of valuable and reusable materials, including precious metals like gold, silver and palladium, as well as base metals such as copper, aluminum, and rare earth elements. Through advanced recycling techniques—such as mechanical separation, pyro-metallurgy, and hydro-metallurgy—these materials can be efficiently extracted and reused in the manufacturing of new electronic products. Materials like, recovered gold and copper can be used in the production of circuit boards, while recycled plastics from electronic casings can be repurposed to create new housings and components. Lithium, cobalt, and nickel recovered from batteries can be reused in new battery cells, reducing dependence on mining and preserving finite natural resources. Recycling in the electronic industry also promotes the development of eco-design principles, where devices are designed for easier disassembly and material recovery. This supports a circular economy, in which materials continuously flow through production and consumption cycles with minimal waste. Therefore, recycling in the electronic industry leads to sustainable materials development, which not only helps recover valuable resources but also reduces environmental impact, lowers production costs, and drives innovation in green manufacturing technologies.

Keywords: E-waste; Recycling; Materials; Sustainable development.

PAPER-ID-111

Evaluation of Sludge Quality from Common Effluent Treatment Plants (CETPs) in Delhi: A Multi-Parameter Approach

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Abstract

Managing industrial sludge is a grave problem in urban India, exacerbated by rapid urbanization, industrialization, and commercialization. In Delhi, 13 Common Effluent Treatment Plants (CETPs) are operational. The major industries registered with CETPs are the electroplating industry and a few other industries, such as dairy, anodizing, and textiles. A pilot study was carried out to characterize CETP sludge. Among the 13 Nos. of CETPs, 03 Nos. of CETP are functional based on biological treatment and other 10 Nos. are functional based on physico-chemical treatment. The sludge's characteristics were intricately tied to the types of industries present in the industrial zone. The study encompassed various physico-chemical parameters, including pH, EC, TDS, moisture content, % carbon, and heavy metal concentrations (Cu, Ni, Fe, Zn, As, Cd, Co, Mn, Cr, Pb, B, and Ba).

Notably, Delhi's industrial landscape is dominated by electroplating industries, dealing with Cu, Ni, Cr, and Zn plating. The study revealed pH (6.51-8.43), EC (1.9 mS to 16.92 mS), moisture (0.22% to 8.37%), and % carbon (1.22% to 18.23%). Low moisture content may result from dried samples collected from CETP sludge storage.

Fe exhibited the highest concentration, followed by Cr, Cu, Mn, Zn, and Ni. Other heavy metals were also present, potentially as impurities in plating compounds or coagulants used in industrial effluent treatment. While the CETP sludge's carbon content suggests potential soil enrichment, the high heavy metal concentrations preclude direct land application due to soil and groundwater contamination risk. Further research is imperative to explore heavy metal recovery and safe disposal methods.

Keywords: CETP; Sludge; Heavy Metals; Characterization; Delhi.

PAPER-ID-112

Influence of Biomass Pretreatment Methods on Hydrogen-Enriched Gasification Processes

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Abstract

Biomass pre-treatment is a critical step to enhance steam gasification toward hydrogen-rich syngas production. Raw biomass typically exhibits high moisture content, low energy density, and structural heterogeneity, which limit conversion efficiency and hydrogen yield. Mechanical pre-treatments such as grinding and densification improve homogeneity, heat transfer, and process stability, while biological ones, including anaerobic digestion, modify biomass composition and generate digestates more suitable for gasification. Besides, chemical pre-treatments using water or acid leaching reduce alkali and alkaline earth metals, mitigating ash-related issues and improving syngas quality, while thermal pre-treatments, particularly torrefaction and hydrothermal carbonization, increase energy density, reactivity, and grindability of biomass. Nevertheless, co-gasification with biochar, plastics, or sludge further acts as a pre-treatment strategy, exploiting synergistic interactions to increase hydrogen selectivity and reduce tar formation. Each method contributes differently to process optimization, though excessive pre-treatment can lead to higher energy demand. Recent research highlights integrated pre-treatments with catalytic reforming and in-situ CO_2 capture for process intensification. The main aim to maximize hydrogen yield while maintaining sustainability, and focus on synergistic strategies, machine learning-based optimization, and techno-economic evaluation to enable scalable hydrogen production.

Keywords: Biomass; Gasification; Hydrogen; Pre-treatment; CO_2 capture.

PAPER-ID-113

Light Olefin Production by Steam Cracking of Waste Derived Pyrolysis Oil

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Abstract

Pyrolysis is one of the possible ways to recycle various wastes, during which the long macromolecules of polymers can be converted into smaller molecules. The products of pyrolysis are gaseous hydrocarbons, pyrolysis oil and solid char. In one hand, the temperature range of pyrolysis is 400-700°C. Further utilization of pyrolysis oil obtained from plastic waste is primarily for energy applications, but there is also the possibility of their petrochemical application. One possible way for petrochemical application is to convert pyrolysis oil into light olefins, from which plastic can be produced again. Light olefins ($<C_4$) can be produced by steam cracking of pyrolysis oil. However, the composition of the pyrolysis oil and the applied process parameters significantly determine their yields and selectivity. Steam cracking of waste derived pyrolysis oil is key in the circular economy, as it enables the utilization of waste plastics as energy and raw materials.

Keywords: Plastic waste; Chemical recycling; Pyrolysis oil; Steam cracking; Circular economy.

PAPER-ID-114

Hydrogen Production by Recycling of Waste Li-Ion Batteries

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Abstract

The use of lithium-ion batteries is significantly increasing, therefore the proper treatment and recycling of waste Li-ion batteries are key issues. The main goal of the recycling of Li-ion batteries are to recover their different parts and value-added conversion of their recyclable units. The recycling of Li-ion batteries can reduce the amount of waste and recover their heavy metal content, which can cause a significant environmental pollution. After collection and sorting of Li-ion batteries, the volume of the waste stream can be reduced by shredding, and then during re-separation, metallic and non-metallic materials are further separated. The non-metallic part mainly contains plastic, for which thermochemical methods such as pyrolysis or gasification are effective recycling processes. The products of pyrolysis and gasification can also be used as alternative fuels or chemical intermediates with quality improvement. Gasification using high temperatures and in the presence of transition metal catalysts can significantly increase the hydrogen content of the products. The amount of hydrogen significantly affected by the process parameters and catalysts. Gasification of waste polymers obtained from Li-ion battery should be a key step in circular economy.

Keywords: Hydrogen; Waste Li-ion battery; Recycling; Catalyst; Gasification.

PAPER-ID-117

Cold Nitrogen Gas Refrigerator-Based Novel Cryogenic Technology for Direct Air Capture

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Abstract

This paper proposes the thermodynamic modelling and analysis of a Novel Low-Cost Cryogenic Carbon Technology (NLCCT) for DAC applications. Initially developed for CO2 capture from industrial flue gas, NLCCT has been adapted and analysed for extracting CO2 from atmospheric air. The working principle is based on the desublimation of CO2, where air is cooled below its desublimation temperature (Tds) according to the partial pressure of CO2 in the atmosphere. For pure CO2 at 1 atm, the desublimation temperature (Tdso) is −78.5°C with a latent heat of desublimation (Hdso) of 571 kJ/kg. For atmospheric CO2 concentrations (~0.004), the Tds is approximately 120 K, increasing the energy requirement and making the optimisation of system design critical.

The NLCCT system uses a Cold Nitrogen Gas Refrigerator (CNGR) in conjunction with a series of cooling chambers to cool the air below Tds. The CNGR consists of multi-stage compressors, intercoolers, and a turboexpander to produce the necessary cold nitrogen refrigerant. This study examines the effect of operating conditions (such as intercooler temperatures) and geometric parameters (like the number of compressor stages) on the energy consumption per tonne of CO2 captured.

Simulation results show that the NLCCT-based DAC system can achieve a high CO2 capture efficiency (~95%) with significantly lower energy (15 GJ/tCO2) consumption and cost ($146/tCO2) compared to conventional DAC systems ($300/tCO2). Notably, no water is used in the process, making it ideal for arid regions. Additionally, the cryogenic nature of the process makes it particularly advantageous for low-temperature climate regions, where ambient cooling loads are naturally reduced. These attributes make NLCCT a promising candidate for scalable, energy-efficient, and sustainable DAC deployment.

Keywords: Cryogenic Carbon Technology; Direct Air Capture; Cold Nitrogen Gas Refrigerator.

PAPER-ID-119

A Closed Loop Approach for Waste Management in Jute Industry by Recycling as Biochar Preparation for Treatment of Effluent and Recalcitrance Study for Agriculture and Environment Application

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Abstract

Jute industries processing was used for development of biochar as adsorbent for effluent treatment in the same industry as recycle prospective. The biochar showed maximum Cu(II) adsorption capacity of 588.25 mgg^{-1}. Experimental facts of Cu (II) adsorption on the biochar fitted better to Freundlich isotherm in comparison to Langmuir isotherm. The treatment effects of synthetic and jute industry wastewater using prepared biochar revealed >95% removal of Cu (II) as well as simultaneous removal of other metal present in effluent. The developed biochar were characterization using FESEM-EDAX, elemental-mapping, FTIR, zeta-potential, Raman spectroscopy, BET-surface area, XRD, XRF, XPS, and modification of surface functional groups for elucidation of removal mechanism. Cu (II) remediation were accomplished by physical and chemisorptions, surface complexation with heteroatom functional groups, ion exchange, electrostatic interaction and precipitation. The recalcitrance potential or biochar stability in soil was established as soil health improvement for agriculture and environment applications. The half-life of control and Cu (II) laden the biochars range from 100 to 1000 years. Short and long term chemical stability and TG-DTA analysis for thermal stability were performed. Calculated recalcitrance parameter (R_{50})for control biochar and Cu (II) laden biochar were 0.44 and 0.51, respectively. Lower R_{50} amount signifies to elevated recalcitrance and better carbon sequestration potential. Minor enhancement in the recalcitrance index of Cu (II) laden biochar was due to Cu (II) complexation with biochar that is also responsible for stability of the biochar in soil.

Keywords: Industrial waste derived adsorbent; Waste water recycle; Heavy metal remediation; Adsorption mechanism; Biochar recalcitrance.

PAPER-ID-120

Waste Management System with Segregation, Real-Time Location Tracking and Reward Mechanism

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Abstract

Lack of awareness regarding waste management and improper waste disposal remain critical environmental challenges, particularly in urban areas. Despite many efforts, there persists a considerable gap between recycling firms and waste generators, leading to unorganized waste, environmental pollution, and missed opportunities for recycling. To address this issue, our project proposes a web-based waste management platform that facilitates the connection between individual waste generators and recycling firms. The system has been developed using HTML, CSS, JavaScript, and Firebase for real-time database management and user authentication, with Cloudinary integrated for image storage. Notable features of the system include separate role-based registration, waste upload and tracking, real-time recycler responses, and location-based pickup coordination, amplifying its efficiency and dependability. Additionally, the platform offers a waste education section and a reward system to promote sustainable practices. This solution thus digitalizes the waste management processes as well as contributes to environmental awareness and community participation.

Keywords — Location-based pickup; Recycling; Reward section; Sustainable practices; Waste education.

PAPER-ID-121

Statistics Driven Comparative Study of Performance Between Conventional and Waste Derived Microbial Fuel Cell

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Abstract

A theoretical comparative study framework is proposed to statistically evaluate the performance and cost metrics of microbial fuel cells (MFCs) built from conventional materials versus those utilizing waste-derived components. The study aims to synthesize and normalize quantitative performance indicators such as power density, chemical oxygen demand (COD) removal efficiency, Coulombic efficiency, and operational lifespan for both conventional (e.g., high-purity electrodes, commercial membranes, synthetic substrates) and waste-based (e.g., recycled electrodes, membranes from waste polymers, organic waste substrates) MFC designs. Cost parameters are systematically estimated from available literature and theoretical market data, accounting for raw material, fabrication, and maintenance considerations. Employing descriptive statistics, hypothesis testing, effect size calculations, and regression modelling, the study identifies statistically significant differences, trade-offs, and success factors under varying operational conditions. This rigorous methodology provides critical, evidence-based insights into the feasibility, environmental benefit, and application potential of waste-derived MFC technologies, ultimately guiding research directions and sustainable engineering decisions.

Keywords: Microbial fuel cell; Waste derived MFC; Conventional MFC; COD removal efficiency; Coulombic efficiency; Power density.

Advances in Waste Management and Resource Utilization

Chief Editor- Rahul Baidya is the Head of the Department - Office of Sustainability, Institute of Engineering & Management, School of University of Engineering and Management Kolkata. He is also Professor & Assistant HoD in the Department of Mechanical Engineering at Institute of Engineering & Management, School of University of Engineering and Management Kolkata, India. He has completed his Masters and PhD (Engineering) from Jadavpur University. He was a Research Fellow (Visiting), Aston Business School, Aston University, Birmingham, UK during 2014 and 2015. He is an executive member of International Society of Waste Management, Air and Water, Kolkata. His research interest includes circular economy, co-processing, resource and energy recovery from waste, supply chain management and optimization engineering. He has published over 65 papers, in refereed journals and in international conference across the globe. He has worked as co-investigator in number of international research projects funded by UKIERI, Royal Academy of Engineering (RAE), British Council and Erasmus+. He has also acted as convenor and scientific committee member of numerous international conferences. He has delivered numerous invited talks in different seminars and conferences.

Editor- Anirban Mukherjee is an Assistant Professor at the Office of Sustainability, Institute of Engineering & Management (IEM), Salt Lake, Kolkata, where he works on advancing sustainable energy solutions and promoting green technologies in education and research. He is about to submit his Ph.D. thesis at Birla Institute of Technology, Mesra, focusing on the design and development of advanced electrocatalysts for the electrochemical reduction of CO_2 into value-added chemicals and fuels. His research particularly emphasizes nanostructured materials such as metal sulfides and MXenes for efficient CO_2 utilization. He holds a B.Tech. in Mechanical Engineering from MAKAUT, West Bengal, and a Master of Engineering in Chemical Engineering from Jadavpur University. He has published extensively in reputed international journals, including Energy Advances and ACS publications, contributing reviews and original research on CO_2 conversion, fuel cells, and nanomaterials. At IEM, he integrates sustainability research with teaching, inspiring future engineers to address global energy and climate challenges.

Editor- Somdipta Bagchi is an environmental engineer, researcher, and educator passionate about creating sustainable solutions for global challenges. She is currently an Assistant Professor at the Office of Sustainability, Institute of Engineering and Management, Kolkata. With a Ph.D. in Civil Engineering (Environmental Engineering) from IIT Bhubaneswar, Somdipta's career has spanned India and the United States, where she worked on innovative approaches to wastewater treatment, PFAS degradation, biochar-based adsorption, and green infrastructure for storm water management. What sets her apart is not just her technical expertise, but also her ability to collaborate across disciplines and cultures. An enthusiastic traveller, Somdipta enjoys learning from diverse perspectives and connecting with people, which fuels her approach to research. For her, science is not just about experiments, but also about building sustainable futures, fostering connections, and encouraging others to reimagine how humans live in harmony with nature.

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