5th International Conference on

"Advances in Water Treatment and Management"

(ICAWTM-26)

March 07-08, 2026

Editor

Prof. Anurag Mudgal

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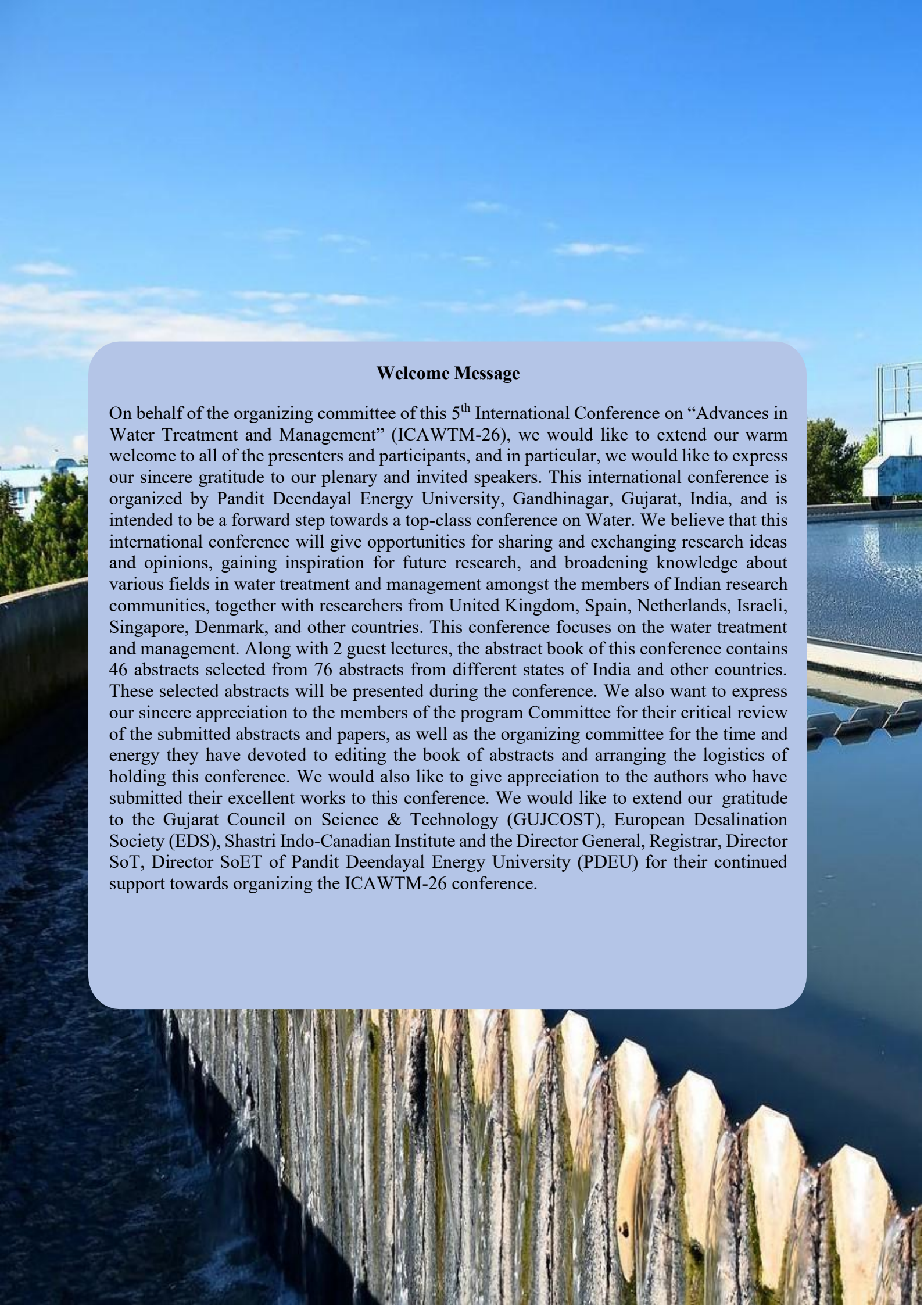

Welcome Message

On behalf of the organizing committee of this 5th International Conference on "Advances in Water Treatment and Management" (ICAWTM-26), we would like to extend our warm welcome to all of the presenters and participants, and in particular, we would like to express our sincere gratitude to our plenary and invited speakers. This international conference is organized by Pandit Deendayal Energy University, Gandhinagar, Gujarat, India, and is intended to be a forward step towards a top-class conference on Water. We believe that this international conference will give opportunities for sharing and exchanging research ideas and opinions, gaining inspiration for future research, and broadening knowledge about various fields in water treatment and management amongst the members of Indian research communities, together with researchers from United Kingdom, Spain, Netherlands, Israeli, Singapore, Denmark, and other countries. This conference focuses on the water treatment and management. Along with 2 guest lectures, the abstract book of this conference contains 46 abstracts selected from 76 abstracts from different states of India and other countries. These selected abstracts will be presented during the conference. We also want to express our sincere appreciation to the members of the program Committee for their critical review of the submitted abstracts and papers, as well as the organizing committee for the time and energy they have devoted to editing the book of abstracts and arranging the logistics of holding this conference. We would also like to give appreciation to the authors who have submitted their excellent works to this conference. We would like to extend our gratitude to the Gujarat Council on Science & Technology (GUJCOST), European Desalination Society (EDS), Shastri Indo-Canadian Institute and the Director General, Registrar, Director SoT, Director SoET of Pandit Deendayal Energy University (PDEU) for their continued support towards organizing the ICAWTM-26 conference.

5th International Conference

on

Advances in Water Treatment and Management

(ICAWTM-26)

March 07-08, 2026

Pandit Deendayal Energy University
Knowledge Corridor, Raisan Village
Gandhinagar, Gujarat-382 426, INDIA

Book of Abstracts

About the Conference

Water is a pressing issue in current times. The increase in the urban population, limiting natural resources and improper water management has increased the need for effective & efficient water treatment strategies. This conference is specially designed to bring together an interdisciplinary team of researchers to share their expertise and research experience on recent trends in water treatment and management. The idea is to bring together like-minded agencies and stakeholders including research organizations, universities, NGOs and SMEs from India and abroad to share their expertise in low-cost water treatment, wastewater treatment, recycle and reuse. Conference includes keynote lectures and invited talks by eminent resource persons from reputed universities and organizations, poster presentations, paper presentations, and interactive sessions. The faculties from different colleges, research scholars, students and scientists will be given opportunity to demonstrate their own works and get valuable suggestions from experts. The conference aims to create an integrated learning environment and encourage academicians, researchers and students to develop various competencies and enhance their self–efficacy in different techniques for affordable and feasible water treatment and management options.

Themes

Thrust Area

- Novel water treatment options for sustainable solutions to clean water scarcity
- Water desalination
- Wastewater treatment and management

Sub Themes to be addressed in this conference include, but not limited to the following

- Membrane and thermal desalination technologies
- Electrochemical systems in water treatment
- Renewable energy-based water treatment technologies and Low-cost solutions
- Novel hybrid systems and module design
- Emerging desalination technologies
- Novel materials for water treatment
- Artificial Intelligence and Machine Learning application in water
- Pre-treatment and post-treatment processes
- Membrane fouling and control
- Brine/concentrate management
- Resources recovery from brine
- Water recycling and reuse
- Wastewater treatment using immobilized microorganism technology
- Sustainability and water management
- Cost effective methods for removal of heavy metals
- Phytoremediation technologies for contamination of organic pollutants
- Bioremediation of contaminated water or wastewater
- Renewable energy applications in groundwater treatment
- Renewable energy applications in industrial water treatment
- Advancing Sustainable Energy: Green Hydrogen Production Through Desalination and Recovery Technologies
- Constructed wetlands for dealing with emerging problem of polluted water
- Ex-situ/ In-situ phytoremediation for treatment of polluted water
- Energy and sustainability, economic evaluation, case studies
- Water policies, governance and planning

- Water, food, energy nexus towards circular economy
- Future trends in water security
- Energy needs for the water sector
- Green technologies for sustainable water resources
- Water and energy in context of industry 4.0
- Decarbonization and future energy systems
- Energy-saving technologies
- Nanotechnology applications in water
- Biomimetics/Nature-based solutions
- Sustainable development goals implementation
- Green Chemistry in Water Treatment: Reducing Environmental Footprints
- Smart Water Networks: AI-Driven Decision Making and Management
- AI for Desalination: Enhancing Efficiency and Reducing Energy Costs
- AI in Predictive Maintenance of Water Treatment Facilities
- AI in the Water-Energy Nexus: Integrating Renewable Solutions
- Green Innovation and Environmental Resilience

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CSIR - CSMCRI, Bhavnagar

Mr. Ajinkya Pandey,

Bharat Ecolabs,

New Delhi

Program at Glance

Day – 1 (March 07, 2026; Saturday)				
09:30 to 10:00	**Registration**			**F Block Foyer**
10:00 to 10:45	**Inauguration Sessions** Introduction and welcome address by **Prof. Anurag Mudgal**, Convener, ICAWTM-25, PDEU Address by **Prof. Philip Davies**, Co-Convener, ICAWTM-25, UoB, UK (online) Address by **Shri Gaurangbhai Vyas,** Chairman, Standing Committee, GMC Gandhinagar Address by **Dr. Narottam Sahoo,** Advisor and Member Secretary, GUJCOST, DST, Gujarat Address by **Shri Niraj Shah**, Head Hazardous Waste Section, GPCB, Gandhinagar Address by **Shri Ajay Prakash** (IAS), Director, Gujarat Energy Development Agency Address by **Prof. Anirbid Sircar**, Patron, Director SoT, PDEU Address by **Prof. Rajesh Patel**, Patron, Director SoET, PDEU Address by **Col (Dr) Rakesh Kumar Srivastawa**, Registrar, PDEU Address by **Prof. S. Sundar Manoharan**, Chief-Patron, Director General, PDEU Inauguration of **ICAWTM-26 Abstract book** Summary of Technical Sessions and Vote of Thanks by **Prof. Vivek Patel**, HoD Mechanical, PDEU			**F-002**
10:45 to 11:30	**High Tea**			**F Block Foyer**
	Visit to Centre of Excellence in Water Treatment and Management			**Near High Rise Hostel**
11:30 to 12:30	**Keynote Lecture** by **Dr. Saroj Sharma,** Principal Scientist, CSIR - CSMCRI, Bhavnagar **Keynote Lecture** by **Mr. Ajinkya Pandey,** Bharat Ecolabs, New Delhi			**F-002**
12:30 to 14:00	**Lunch**			**PDEU Canteen**
14:00 to 17:00	**Track-1** Paper Presentation	**Track-2** Paper Presentation	**Track-3** Paper Presentation	**F-002 F-003 F-004**
Day – 2 (March 08, 2026; Sunday)				
08:30 to 09:00	**High Tea**			**F Block**
09:00 to 12:00	**Track-4** Paper Presentation	**Track-5** Paper Presentation	**Track-6** **Paper Presentation**	**F-002 F-003 F-004**
12:00 to 12:30	**Certificate Distribution and Valedictory Session**			**1st Floor Corridor**
12:30 to 01:30	**Lunch**			
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Paper Presentations

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Track 1 - Advanced Technologies for Sustainable Wastewater Treatment

Sustainable Wastewater Treatment Using a Visible-Light-Driven Coiled Flow Inverter Photoreactor

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Abstract
Rapid urbanization, declining freshwater resources, and improper wastewater management have intensified the need for sustainable, efficient, and affordable water treatment technologies. This study presents a coiled flow inverter (CFI) photoreactor as an advanced and scalable platform for sustainable wastewater treatment under visible-light irradiation. The unique helical configuration of the CFI enhances fluid mixing, mass and heat transfer, and light utilization, leading to improved treatment efficiency compared to conventional reactors. The performance of the CFI photoreactor was evaluated for the removal of pharmaceutical and inorganic contaminants using integrated photocatalytic and photo-biocatalytic approaches. In the photocatalytic system, Co–Ni tungstate anchored on g-C_3N_4 (CoNiW-gCN) was employed for paracetamol degradation, achieving over 99% removal of 10 ppm paracetamol within 36 min, with degradation rates 2.7 times higher than those observed in a batch reactor. In parallel, a CFI-assisted photo-biocatalytic denitrification system combining an FexOy/g-C_3N_4 photocatalyst with an in-situ developed electroactive biofilm achieved up to 98% nitrate removal within 60 min, with negligible accumulation of nitrite or ammonium. Key operating parameters, including catalyst loading, contaminant concentration, light intensity, and recycle ratio, were optimized using response surface methodology, showing excellent agreement between experimental and predicted results. Mechanistic investigations revealed enhanced charge separation, efficient electron transfer, and selective pollutant transformation supported by metabolically versatile microbial communities. Overall, the CFI photoreactor demonstrates strong potential as a low-energy, cost-effective, and scalable solution for wastewater treatment, recycle, and reuse, contributing to sustainable water management strategies.

Keywords: coiled flow inverter; photoreactor; photo-biocatalysis; denitrification; wastewater treatment

Planetary Boundary LCA of Molasses-Based Bioethanol Production Incorporating Zero Liquid Discharge Wastewater Treatment via Evaporation and Incineration

Anita Kokate[a], Surendra Singh Kachhwaha[a,*], Pravin Kodgire[b]

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[b] *Dept of Chemical Engineering, School of Energy Technology, Pandit Deendayal Energy University, Gandhinagar, 382426, India*

Abstract
Conventional life cycle assessment (LCA) of bioethanol production is inherently comparative; such assessments do not evaluate compliance with the Earth's ecological limits. This study aims to quantify the alignment of molasses-based bioethanol production with its allocated planetary safe operating space through a planetary boundary-based life cycle assessment (PB-LCA). A gate-to-gate PB-LCA is conducted for an Indian molasses-based bioethanol plant integrated with multiple-effect evaporation and incineration-based zero liquid discharge (ZLD) spent wash treatment. Sixteen environmental impact categories are evaluated using the Impact world+ method. Global planetary boundaries are first downscaled to the Indian context using an egalitarian approach. The national share is then allocated to the bioethanol sector using a utilitarian, consumption-based method. Seven of sixteen impact categories exceed their allocated limits. Climate change shows a transgression of 101%, freshwater eutrophication of 135%, land use of 45%, particulate matter of 1646%, human toxicity (non-cancer) of 841%, freshwater ecotoxicity of 1.03×10^6% and mineral resource use of 159%. Blending analysis (E0 to E100) indicates that increasing bioethanol shares reduces climate change and fossil resource pressures, whereas high blends substantially increase burdens on freshwater, land use, and ecotoxicity. The blends, ranging from E20 to E50, offer balanced performance. The results show relative climate change and fossil resource-related benefits; however, absolute sustainability is not achieved. Toxicity and combustion-related impacts dominate boundary exceedance, underscoring the need for innovative process development, optimization and policy design in reference to the PB-LCA framework.

Keywords: Bioethanol; Planetary boundary-based LCA; Absolute environmental sustainability (AESA); Ethanol blending scenarios; Zero liquid discharge (ZLD)

Iron Oxide Nanoparticles Coated with Biodegradable Poly(Glycerol–Citric Acid) based hyper-branched Dendritic structure for Water Desalination

Hitesh M Rakhade [1], Ajay Kumar Gupta [*]

Ganpat University – Mehsana Urban Institute of Sciences, Kherva, Gujarat, India

** Ganpat University- Research & development, Kherva, Gujarat, India*

Abstract

Iron oxide nanoparticles coated with Biodegradable poly(glycerol–citric acid) (PGCA) based hyper-branched dendritic structure (HDS) have emerged as promising materials for sustainable water treatment due to their eco-friendly composition, high surface functionality, and magnetic separability. In this study, PGCA-HDS were synthesized via a stepwise esterification approach and subsequently coated onto iron oxide nanoparticles to obtain a stable, water-dispersible hybrid nanomaterial. Comprehensive characterization using FTIR, XRD, DLS, zeta potential, FE-SEM and VSM confirmed successful coating of PGCA-HDS, crystalline magnetite structure, nanoscale size, surface charge stability, and superparamagnetic behaviour. The water treatment performance of the iron oxide nanoparticles PGCA-HDS was evaluated for total dissolved solids (TDS) reduction around 40%, heavy metal ion removal (Pb^{2+}, Cd^{2+}) up to 90% and also around 80% removal of total Hardness of water from aqueous solutions. This cost-effective, sustainable approach offers potential applications in industrial wastewater treatment by reducing TDS, TH, and heavy metal ions, improving overall water quality. The novelty of this work lies in combining PGCA-HDS surface modification with iron oxide nanoparticles to improve adsorption efficiency and enable easy magnetic recovery, providing a scalable solution for wastewater remediation technologies and desalination.

Keywords: Poly(glycerol–citric acid) based Hyper-branched dendritic structure, Iron oxide nanoparticles, Biodegradable, Desalination, Heavy metal removal, Total dissolved solids, Water hardness removal.

Data-Driven Thermo-Economic Assessment of Multi-Effect Distillation Systems Using Ensemble Machine Learning Models

Rahul Deharkar[a*], Tanishi Das[a], Nandini Chaudhary[a]

[a]*Pandit Deendayal Energy University, India*

Abstract

Thermo-economic evaluation of Multi-Effect Distillation (MED) systems traditionally relies on detailed first-principle models involving iterative mass and energy balance calculations coupled with economic correlations. While such models provide high physical fidelity, they are computationally intensive and less suitable for rapid design exploration, sensitivity analysis, and real-time decision-making. Recent studies have demonstrated the techno-economic viability of decentralized and medium-scale MED systems through detailed thermo-economic modelling and Taguchi-based optimization; however, a data-driven predictive framework capable of instantaneously estimating performance and cost metrics is still lacking. In this study, a machine-learning-based surrogate modelling approach is proposed to predict the thermo-economic performance of MED systems using Random Forest (RF) and Extreme Gradient Boosting (XGBoost) algorithms. A comprehensive dataset was generated from a validated MATLAB-based thermo-economic MED model, covering a wide operating envelope relevant to decentralized applications. Key design and operating inputs include the number of effects, heat-transfer area per effect, motive steam flow rate, steam pressure, and feed conditions, while the target outputs comprise distillate production rate, performance ratio, freshwater cost, and total annualized cost. The RF and XGBoost models were trained and tested using systematic data splitting and cross-validation strategies. Model performance was evaluated using statistical metrics such as coefficient of determination (R^2), root-mean-square error (RMSE), and mean absolute percentage error (MAPE). Both models demonstrated excellent predictive capability, with XGBoost consistently outperforming Random Forest due to its superior handling of nonlinear interactions and parameter coupling inherent in MED thermo-economic behavior. Feature-importance and SHAP-based interpretability analyses revealed that the number of effects and motive steam flow rate dominate thermodynamic performance, whereas heat-transfer area and steam pressure exert a stronger influence on economic outcomes. The developed ML models enable near-instantaneous prediction of MED performance and cost metrics with accuracy comparable to physics-based simulations, while reducing computational time by several orders of magnitude. The proposed framework is particularly suitable for rapid feasibility screening, multi-objective optimization, digital-twin development, and integration with higher-level decision-support tools for sustainable water infrastructure planning. Overall, this work demonstrates that ensemble machine-learning techniques can serve as robust, explainable, and scalable surrogates for complex thermo-economic models, significantly advancing the design and deployment of decentralized MED systems.

Keywords: Multi-Effect Distillation; Thermo-economic analysis; Machine learning; Random Forest; XGBoost; Decentralized desalination.

Smart Wastewater Treatment Plant: Energy-Efficient using Machine Learning Techniques for Economical and Sustainable Design

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Abstract

Wastewater treatment plants (WWTPs) represent a major share of energy demand within urban water infrastructure, making energy-aware operation a critical requirement for both economic feasibility and environmental sustainability. This study develops a smart data-driven framework for predicting WWTP energy consumption using machine learning, with the objective of supporting energy-efficient and cost-effective plant design and operation. A comparative evaluation of several machine learning models is carried out using real operational data, encompassing kernel-based methods, ensemble learners, instance-based algorithms, and neural network architecture. To ensure robust and unbiased model calibration, Bayesian optimization is employed for hyperparameter tuning across all candidate models. Beyond conventional static predictors, the proposed framework explicitly accounts for the dynamic nature of wastewater treatment processes by integrating time-lagged energy and process measurements, enabling the construction of dynamic prediction models. In addition to widely used algorithms, recent learning paradigms capable of capturing temporal dependencies are examined to enhance forecasting reliability. The results demonstrate that models incorporating lagged information consistently outperform static and reduced-feature counterparts, confirming the importance of temporal memory in energy demand prediction. From an operational perspective, improved forecasting accuracy directly translates into reduced energy costs, optimized resource allocation, lower greenhouse gas emissions, and enhanced long-term sustainability of WWTP operations. Overall, the study highlights the potential of combining advanced machine learning, temporal modeling, and optimization techniques as a practical pathway toward economically viable and sustainable wastewater treatment systems.

Keywords: Wastewater treatment; Energy prediction; Machine learning; Time-lagged modelling; Bayesian optimization; Sustainability

Advanced Engineering of Nanocomposite-Functionalized Biofiltration

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Abstract

Most point-of-use (PoU) water filtration systems operate as passive devices. They have limited hydraulic optimization, are chemically intensive antimicrobial agents dependent, and lack integrated mechanisms for real-time performance decline indication. This work addresses these limitations through the development of a smart biofiltration cartridge. The design integrates green synthesized, plant extract–derived antimicrobial nanoparticles, highly specific aptamers to increase the bactericidal efficiency embedded in a triply periodic minimal surface (TPMS) gyroid architecture. The gyroid structure is engineered to maximize specific surface area, improve mass transfer kinetics, and maintain low pressure drop under gravity-driven flow conditions. The internal surfaces of the monolithic scaffold are further functionalized for aptamer immobilization by increasing the surface area of contact, enabling selective contaminant capture and improved filtration specificity. Antimicrobial nanoparticles synthesized using Neem (Azadirachta indica) leaf extract, eliminated the use of toxic chemical reducing agents and improved the environmental sustainability of the system. A colorimetric indicator system is incorporated to provide real-time visual feedback on cartridge saturation, addressing a critical limitation of existing household filters. Fabrication can be proved to be best achieved through stereolithography-based additive manufacturing followed by surface activation and covalent bioconjugation of the nanoparticles using EDC/NHS chemistry. This work demonstrates a proof-of-concept for an integrated, multifunctional filtration platform that integrates, advanced filtration matrix design, innovative pathogen detection method using aptamers and killing them using nanoparticles within a single replaceable cartridge, establishing a foundation for future development of next-generation water purification technologies.

Keywords: TPMS gyroid; green synthesis; Azadirachta indica; antimicrobial biofilter; aptamer functionalization; water purification

Track 2 – AI-ML in Predictive Maintenance of Water Treatment Facilities

Machine Learning–Based Prediction of Water Treatment Plant Efficiency

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Abstract
Everyday living depends on clean, trustworthy water - still changing conditions like weather, treatment chemicals, or shifts in incoming water quality affect how raw streams are made safe. When so many variables mix, relying only on old-style planning tools can make it hard to guess actual results. Instead, recent work looks at using past records - both from machines and outside forces - to forecast output using smart algorithms that learn patterns over time. One by one, two approaches emerged - Random Forest Regression and Linear Regression - put through their paces with data types such as inflow traits, chemical signs, weather markers, along with temporal details. Each was judged through average prediction error and how well predicted outcomes lined up with observed results. Surprisingly clear, the Random Forest setup outperformed the simpler linear version, delivering tighter forecasts and clearer insight into shifting outputs. What shows up here is how sometimes machines learn fast when handling water quality tasks. Instead of guessing, systems like combined learning setups give workers clearer views on what might happen next. That kind of insight doesn't replace human judgment but adds weight behind choices made at treatment sites. Efficiency often climbs simply because guesses turn into tested forecasts across facilities.

Keywords: Machine Learning; Random Forest; Linear Regression; efficiency prediction; water management

Employing Sensitivity Analysis Methods to Assess Neural Network Models in Water Quality Prediction

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Abstract
The effectiveness of sensitivity analysis of neural networks in choosing input and elucidating its impact on output prediction is demonstrated in the current study. This analysis employs average mutual information, Pearson correlation coefficient, and local sensitivity analysis. The research projected three essential water quality indicators: chemical oxygen demand (COD), biochemical oxygen demand (BOD), and dissolved oxygen (DO). Artificial neural networks (ANN) are employed to model three portions of the Mula-Mutha River. It will aid in identifying the primary influencing factors, hence enhancing model efficiency by reducing complexity through the elimination of superfluous variables. Sensitivity analysis facilitated the identification of the most critical input factors, hence decreasing input complexity while preserving predictive accuracy. Global sensitivity analysis is ineffective for extensive models; hence, local sensitivity analysis methods were employed for feedforward backpropagation neural networks (FFBP-NN). The suggested AI models were assessed utilising conventional performance criteria, such as the correlation coefficient (R), Root Mean Squared Error (RMSE), and Mean Absolute Error (MAE). The investigation indicates that the primary variables impacting the prediction of Dissolved Oxygen (DO) are Conductivity (EC), Total Solids (TS), Alkalinity (ALK), and pH. The inclusion of dissolved oxygen and nitrites enhanced the model's capacity to predict both biological oxygen demand and chemical oxygen need. But we also notice that the importance of input factors varies over the river section, relying on the contamination and pollution source. This study offers valuable guidance for selecting factors in the building of an AI model that enhances the accurate prediction of water quality measurements.

Keywords: Sensitivity analysis, Average mutual information, water quality analysis, prediction

Hydraulic Simulation of Benchmark Water Distribution Systems Using EPANET 2.2

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Abstract
Reliable hydraulic simulation is crucial for understanding water distribution system (WDS) behaviour and for benchmarking optimization and control methods. This paper develops benchmark WDS models using the EPANET 2.2 simulation engine, providing a consistent and reproducible setup for hydraulic analysis. The framework represents key network components—pipes, junctions, pumps, valves, and storage units—and supports both steady-state and extended-period simulations. Using EPANET, the study computes nodal pressures and link flows across the network to examine hydraulic performance under varying operating conditions and to identify spatial variations in service levels. The resulting benchmark models serve as a standardized testbed for performance assessment, method validation, and comparative studies. This work supports future research in WDS monitoring, optimization, and operational planning by offering a transparent simulation foundation that can be reused and extended by the community.

Keywords: Benchmark Network Models, EPANET 2.2, Extended-Period Simulation, Hydraulic Simulation, Water Distribution Systems (WDS).

Machine Learning-Based Correlation of Structural and Analytical Parameters with TiO2 Photocatalytic Activity towards Dye Degradation

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ABSTRACT
The synthesis and optimization of the photocatalyst such as TiO2 are time consuming and labour intensive processes that require extensive experimental trials for achieving high photocatalytic performance. Identifying clear the relationship between synthetic conditions, analytical parameter, structural parameter with photocatalytic performance such as dye degradation efficiency (DDE) remains a challenge. In this work machine learning techniques were employed to establish the correlation between structural parameters and analytical parameters and DDE to enable efficient prediction of the photocatalytic performance. A dataset comprising of 425 data points was collected from the different literature sources. Correlation analysis and Pearson correlation were first applied to examine the relationship between the input parameters and DDE. Subsequently, several ML models, including Linear regression(LR), Random forest(RF), XG boost, and Cat boost were developed and evaluated. Model performance was assessed using multiple evaluation metrics, namely the coefficient of determination (R2), Root mean square error (RMSE), mean absolute error (MAE), and standard error(SE). Among the tested models, XG boost demonstrated the best predictive performance achieving an R2 value of 0.74, RMSE of 15.76, MAE of 8.08 and a standard error of 15.73. These results indicate that XG Boost is a reliable and effective model for predicting the photocatalytic performance of TiO2-based photocatalysts, offering a promising approach to reduce experimental effort and accelerate photocatalyst design.

Keywords: TiO2, Machine Learning, Photocatalyst, Dye degradation efficiency, Machine learning models.

Experimental Investigation of Energy-Efficient Thermo-Hydraulic Performance of Circular Tubes Using Notched Circular Ring Wire Mesh Inserts

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Abstract

The current research is based on the experimental investigation of circular tube employed with three innovative design of wire mesh insert to enhance the thermo-hydraulic behaviour of fluid flowing inside the circular tube. Experimental test was conducted in a controlled environment with water as working fluid having Reynolds number ranging from 4000 to 15000 and heater power from 400 to 800W and with three new geometries of wire mesh insert namely wire mesh roll (WMR), circular ring wire mesh (CRWM) and notched circular ring wire mesh (NCRWM). The influence of key design parameters, including mesh porosity (0.90-0.70)), the presence of notches, and insert pitch length (40–80 mm), was examined. The thermal and hydraulic performance of the inserts was evaluated using the Nusselt number, friction factor, and the Performance Evaluation Criterion (PEC).
Initial comparisons among a plain tube, WMR (0.90porosity), and CRWM (0.90porosity) revealed that the CRWM configuration consistently delivered higher heat transfer enhancement, but with increased flow resistance. PEC analysis demonstrated that CRWM outperformed WMR prompting further investigation of CRWM inserts with varying porosities and notch geometries. Experimental results demonstrate that the introduction of notches has an insignificant impact on Nusselt number enhancement; however, it leads to a reduction in pressure drop, which consequently enhances the overall Performance Evaluation Criterion .Among the tested porosities, the notched CRWM (0.75porosity) achieved an average PEC 9.1% higher than that of the unnotched CRWM (0.90porosity) , confirming the positive role of optimized porosity and notch design.
Further experiments on notched CRWM (0.75porosity) with different pitch lengths (40, 50, and 80 mm) indicated that a 50 mm pitch provides the best thermo-hydraulic balance, yielding PEC improvements of 5.8% and 5.2% compared to 80 mm and 40 mm pitches, respectively. Based on the experimental results obtained, the notched CRWM inserts consistently demonstrated superior heat transfer enhancement compared to the other configurations examined. The data reveal that thermal performance is governed by the combined influence of mesh porosity, notch geometry, and insert pitch length, with certain combinations yielding notably higher performance gains. These findings suggest that notched CRWM inserts can serve as a promising passive enhancement technique for absorber tubes in solar parabolic trough collectors which may contribute in improving thermal efficiency for effective utilization of solar energy in practical applications

Keywords: Circular Ring Wire Mesh ; Friction factor; Heat transfer enhancement; Notched circular ring wire mesh inserts; Nusselt number; Performance Evaluation Criterion ; Reynolds number; Solar parabolic trough collector; Thermo-hydraulic performance;

Effect of Ni loading on γ-Al_2O_3 supported catalysts for CO_2 Methanation

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Abstract

CO_2 methanation offers a promising approach to mitigate CO_2 emissions while addressing global energy demands by converting CO_2 into methane (CH_4), a renewable and versatile fuel. The chemical reaction and standard heat of reaction for CO_2 methanation are given by:

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O \qquad \Delta H^{\circ}_{rx}(298\ K) = -165\ KJ/mol$$

Ni-based catalysts are among the most promising candidates for CO_2 methanation due to their high catalytic activity, low cost, and favourable selectivity toward methane. However, the influence of Ni metal loading on a low-temperature-calcined catalysts, as well as its effect on physicochemical properties and catalytic performance remains a critical area of investigation. In this study, Ni/Al_2O_3 catalysts with nickel loadings ranging from 10 to 50 wt.% were synthesized via the incipient wetness impregnation method. The base catalyst containing 10 wt.% Ni was prepared first, and higher loadings were obtained through sequential impregnation and drying steps, enabling controlled, systematic increases in metal content. All samples were calcined at 300°C for 2 h and subsequently reduced in situ under hydrogen at 600°C for 2 h before the reaction. The catalysts were characterized by XRD, H_2-TPR, and TEM to assess their physicochemical properties. The CO_2 methanation reactions were conducted in a fixed-bed quartz tube reactor at atmospheric pressure across a temperature range of 230-300°C. This work aims to correlate the effect of Ni loading with catalytic performance and structural properties to determine the optimum loading for maximum CO_2 conversion. The results highlight the critical role of metal dispersion and reducibility, offering valuable insights into achieving enhanced methanation activity.

Keywords: CO_2 utilization, Methanation, Ni-based catalyst, Metal loading, optimization

Integrating Ensemble Learning and Fuzzy Intelligence for Water Quality Index Prediction in the Sutlej River

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Abstract

The Sutlej River is one of the major transboundary rivers in northern India, playing a critical role in irrigation, drinking water supply, and industrial activities in Punjab and adjoining regions. Due to rapid urbanization, intensive agriculture, industrial discharge, and untreated domestic wastewater, the water quality of the river has severely degraded within recent years. It essentially requires continuous monitoring and assessment. Most of the traditional methods applied for water quality assessment are time-consuming and incapable of capturing complex nonlinear relationships of multiple water quality parameters. In the presented study, WQI analysis and prediction for Sutlej River were made using five years of monitoring data, availed from the Central Pollution Control Board, India, for 2018-2023. WQI values are computed based on the crucial physicochemical and biological parameters comprising pH, TDS, BOD, COD, temperature, fecal coliform, and total coliform. For the prediction of the WQI, advanced machine learning models incorporating XGBoost and Fuzzy ANN are employed in this paper. The work represents novelty in the application of ensemble learning and fuzzy-based intelligence for the WQI prediction of the Sutlej River through the use of CPCB data. Results from the study have shown that machine learning models can guarantee a more accurate and efficient WQI prediction.

Keywords: WQI analysis; machine learning; XGBoost; Fuzzy ANN

Hybrid Statistical–Machine Learning Bias Correction of Historical CMIP6 Wind Speed for Climate Change Impact Assessment

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Abstract

Climate change is expected to significantly modify near-surface wind regimes, influencing renewable energy potential, extreme weather risks, and climate impact assessments under future Shared Socioeconomic Pathways (SSPs). Reliable regional-scale wind speed projections are therefore essential; however, CMIP6 general circulation models (GCMs) often exhibit systematic biases that limit their direct applicability. To address this limitation, this study proposes a hybrid bias-correction framework that integrates conventional statistical bias-correction techniques with machine-learning models to improve daily 10 m wind speed simulations. ERA5 reanalysis data were used as the reference dataset, with historical records covering the period 1990–2014. Model training was conducted for 1990–2005, while independent validation was performed for 2006–2014. In the first stage, statistical bias-correction methods, including quantile mapping variants and adjustment techniques, were applied as baseline downscaling approaches. In the second stage, five machine-learning regression models—Extreme Gradient Boosting (XGBoost), k-Nearest Neighbours (KNN) and Random Forest (RF) were employed to further correct residual biases and capture nonlinear relationships between GCM outputs and observed wind speeds. Model performance was evaluated using root mean square error (RMSE), mean bias, coefficient of determination (R^2), and distribution-based skill scores. Compared to raw CMIP6 simulations (RMSE = 1.076 m s^{-1}, R = 0.748), the hybrid framework reduced RMSE to 0.844 m s^{-1} using XGBoost, increased correlation to 0.817, improved the standard deviation ratio from 1.065 to 0.895, and achieved Perkins Skill Score values between 0.827 and 0.841, while the AS–RF approach reduced mean bias to 0.113 m s^{-1} during the validation period (2006–2014). This hybrid approach provides a robust and scalable methodology for enhancing wind speed projections, supporting more reliable climate change impact assessments and future SSP-based analyses.

Keywords: Bias correction; Climate change; CMIP6; Machine learning; Wind speed

Track 3 - Adsorbents and Bio-Sorption Technologies for Industral Wastewater Treatment

Phosphorus-doped Graphitic Carbon Nitride-Supported Bimetal Sulphides: A Powerful S-Scheme Redox Photocatalyst

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Abstract

Inorganic and organic pollutants discharge in water bodies is a worldwide problem which is affecting human and aquatic life. Nitrate, a hazardous inorganic pollutant from agriculture and industry, is limited by WHO to 10 mg N/L in drinking water. Benzyl alcohol (BAl), an organic compound from pharmaceuticals, detergents, and dyes are hazardous pollutants linked to serious toxic effects such as muscle paralysis and respiratory failure. Addressing these issues, an S-scheme heterojunction between iron nickel sulphide ($FeNi_2S_4$, FNS) and phosphorous doped graphitic carbon nitride (P-g-C_3N_4, P-CN) is fabricated by the ultrasonication–calcination method for simultaneous nitrate reduction and benzyl alcohol oxidation. The synthesized material is characterized using different physicochemical, electrochemical, and optical techniques. FNS/P-CN composite with 5% w/w of FNS, showed the best activity for nitrate reduction, outperforming the individual FNS and P-CN by ~27 and 56%, respectively. ~97 and 75% conversion of 100 ppm nitrate and 7500 ppm of BAl is achieved, respectively. Nitrate reduction and BAl oxidation reactions are carried out over P-CN and FNS, respectively. The enhanced photocatalytic performance is attributed to S-scheme charge transfer pathway, corroborated by kelvin probe force microscopy. electron paramagnetic resonance and x-ray photoelectron spectroscopy. The FNS/P-CN photocatalyst demonstrated excellent stability with negligible activity loss after five reaction regeneration cycles. This study highlights the potential of S-scheme heterojunctions as robust and sustainable photocatalysts for coupled redox reactions, offering a promising strategy for advanced water treatment and pollutant remediation.

Keywords: Nitrate reduction; Benzyl alcohol oxidation; S-scheme heterojunction; Iron nickel sulphide; Phosphorous doped graphitic carbon nitride.

Kinetic Insights into the Adsorption Behavior of Fly Ash–Derived Zeolite for the Removal of Nickel Contaminants Common in Groundwater and Produced Water

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Abstract

Nickel contamination has become a serious concern in both groundwater and produced water due to increasing industrial discharge and petroleum production activities. This study explores a sustainable approach to mitigate this issue by synthesizing zeolitic material from lignite fly ash and investigating its adsorption kinetics for nickel ion removal. The primary objective is to transform an abundant industrial byproduct—fly ash—into a high-value adsorbent, while systematically evaluating the kinetic mechanisms and removal efficiency under variable process conditions.

Fly ash collected from Neyveli Lignite Corporation was subjected to an alkali fusion process using sodium hydroxide, followed by hydrothermal treatment to produce crystalline zeolite. The synthesized material was characterized using X-ray diffraction (XRD), scanning electron microscopy (SEM), and Brunauer–Emmett–Teller (BET) surface area analysis to determine its structure, morphology, and porosity. Batch adsorption experiments were performed to analyze the effects of contact time, temperature, and adsorbent dosage on nickel ion removal. Kinetic models, including pseudo-first-order and pseudo-second-order equations, were applied to describe the adsorption mechanism and rate behavior.

The synthesized fly ash–derived zeolite exhibited high crystallinity and a well-developed porous structure, making it suitable for efficient metal ion adsorption. Nickel removal efficiency increased with temperature and adsorbent dosage, indicating an endothermic process. The adsorption data closely fitted the pseudo-second-order kinetic model ($R^2 > 0.99$), confirming chemisorption as the dominant mechanism. The estimated activation energy (~40 kJ/mol) further supported the surface-controlled adsorption process. Both batch and column studies demonstrated consistent removal efficiency and strong regeneration potential, emphasizing the material's reusability for multiple adsorption cycles.

This research provides critical kinetic insights into the adsorption mechanism of nickel removal using fly ash–derived zeolite, addressing a dual challenge of groundwater and produced water contamination. The study demonstrates an innovative pathway for waste-to-resource conversion, aligning with principles of sustainable water treatment and circular economy. The findings highlight the material's high efficiency, stability, and regeneration capacity, making it a promising candidate for scalable heavy metal remediation in industrial and environmental applications.

Keywords: Fly ash–derived zeolite; Nickel removal; Adsorption mechanism; Groundwater and produced water treatment; Waste valorization; Sustainable water purification.

Coconut Husk as a Sustainable, Low-Cost Bio-Adsorbent for Textile Dye Effluent Treatment

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Abstract

The textile industry is one of the largest consumers of wastewater and water worldwide, and also one of the biggest contributors to industrial water pollution if effluents aren't treated correctly. From dyeing and printing to washing and finishing, every stage generates complex wastewater loaded with color, chemicals, and organic pollutants.

Without proper textile industry effluent treatment, these discharges contaminate rivers, harm aquatic life, and disrupt downstream water use for agriculture and communities

The India's dye and pigment market is expected to touch USD 1.70 billion by 2033. The market is driven by high demand from the textiles, paints, coatings, and plastics industries, growing at a CAGR of roughly 7%. India is a major global manufacturing hub for dyes and pigments, with substantial export potential.

Effluent treatment in the textile industry is expensive due to the high volume of effluent produced, containing complex pollutants like dyes, heavy metals, and salts, which require multi-stage, energy-intensive, and chemical-heavy processing to meet stringent environmental regulations. So using eco-friendly adsorbent for ecofriendly treatment , treating dye contaminated water is an effective way for water treatment without causing any pollution and at the same time cost effective.

coconut husk is an effective, sustainable, and low-cost natural adsorbent for treating dye-contaminated water in the textile industry. It effectively removes various dyes (e.g., methylene blue, crystal violet) by utilizing its high lignin and cellulose content, reducing colour, particularly when activated or used as powder and helps in industrial pollution control.

Companies like Western Adsorbents & Catalysts, rxsol chemo pharma international, and Global Adsorbents are involved in producing high-quality activated carbon from coconut shells. These companies can provide activated carbon to textile industries for their effluent treatment. Coconut shells are converted into granular or powdered activated carbon, offering a large surface area for adsorption. The technology is highlighted as a sustainable "green" method that avoids secondary pollution, using natural, agricultural waste. Coconut-based carbon is a cost-effective, renewable, and locally available material (especially in India) that can be activated using chemicals like H_2SO_4 and $ZnCl_2$.

Keywords: Coconut husk; Adsorption; ecofriendly wastewater treatment; cost effective treatment; decolorization; industrial pollution control.

Synthesis, Characterizations, and applications of BiOBr for photocatalytic degradation of dyes

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Abstract

The rapid growth of industrial activities has resulted in substantial increase in wastewater generation, causing serious threats to human health and the environment. Therefore, the development of efficient and visible light active photocatalysis for textile wastewater treatment has attracted significant research interest. In this work, the photocatalytic degradation of crystal violet using Bismuth Oxybromide (BiOBr) under visible light irradiation is presented. BiOBr was synthesized using a simplistic, cost-effective and time-efficient method and then characterized to estimate its structural, morphological, and physiochemical properties.

The prepared BiOBr was characterized using field-emission scanning electron microscopy (FESEM), Fourier transform infrared spectroscopy (FT-IR), X- ray diffraction (XRD) and thermogravimetric analysis (TGA). Also, its band gap was determined by plotting the data of UV-Visible diffuse reflectance spectroscopy (DRS) in the form of tauc plot. The photocatalytic activity of BiOBr was determined by observing the degradation of crystal violet under visible-light illumination. The results showed that BiOBr exhibits excellent photocatalytic performance due to its suitable band gap and layered crystal structure, which facilitate efficient charge separation and enhanced light adsorption.

Keywords : Photocatalysis, Bismuth Oxybromide, adsorption

Sustainable approach for simulation of heavy metal–bearing suspended solids in oilfield produced water

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Abstract

Oilfield produced water (OPW) is one of the largest waste streams of oil and gas industry. OPW consists of complex mixture of dissolved solids, hydrocarbons, salts, chemical additives and suspended solids, enriched with heavy metals. The cumulative interactions of these contaminants with soil and water pose significant challenges due to their mobility, persistence and potential toxicity (Fakru'l Razi et al.2009). These particulate bound metals can cause long-term contamination of subsurface and groundwater resources (Freeze & Cheery, 1979). This study proposes a simulation-based modeling framework to investigate the separation and transport behavior of heavy metal bearing suspended solids in OPW.

The focus of this study is on modeling the key physical and chemical processes controlling the transport, separation and partitioning of heavy metal-bearing suspended solids in OPW. Moreover, a process-based computational approach is adopted, which avoids dependence on site-specific experimental datasets to ensure applicability to various oilfield situations. Hydrocyclone separators serve as model physical separation devices due to their common application for the removal of suspended solids and dispersed phases in produced water treatment (Veil et al.,2004; Fakru'l Razi et al.2009).

Using a predictive and process-based modeling approach, this work aims to identify the important factors controlling the environmental risk of contaminants in OPW disposal (Veil et al.,2004). The modeling work employs CFD to analyze the flow and particle trajectories during the separation processes, which would also assist in investigations into separation efficiency. The work also enables the evaluation of suspended solid removal performance and the associated reduction of heavy metal loading. The framework is evaluated by linking separation performance to reduction of contaminant transport in water systems. Curtailing of particulate bound heavy metals would significantly help with reduction in soil contamination and groundwater pollution (Bear, 1972). This study on integration of separation modelling with environmental consideration showcases the role of simulation tools in sustainable produced water management. The proposed approach is a flexible and scalable platform for treatment strategies for the evaluation and environment-friendly decision support for oilfield operations (Šimůnek et al., 2016).

Keywords*: Oilfield produced water, soil-water contamination, heavy metals, CFD modeling, Hydrocyclone separation.*

Structural and Surface Engineering of Functionalized Biochar Pellets for Ciprofloxacin Adsorption: A Systematic Study on Mass Transport and Binder Interactions

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Abstract

The increasing occurrence of pharmaceutical contaminants such as ciprofloxacin (CIP) in aquatic systems necessitates the development of mechanically robust, high-performance adsorbents suitable for scalable water treatment. In this study, functionalized biochar derived from biomass precursors was structurally engineered into pelletized adsorbents using inorganic binders (e.g. clay) to overcome the handling and separation limitations associated with powdered carbons. The work systematically investigates how binder incorporation and pellet size influence surface chemistry, mass transfer behaviour, and adsorption performance.

Pelletized biochar adsorbents were prepared with controlled binder content (3 % binder) and size fractions, followed by detailed physicochemical characterization to evaluate textural properties, surface functionality, and structural integrity. Batch adsorption experiments were conducted over a range of initial ciprofloxacin concentrations (100 ppm), adsorbent dosages (0.15 – 1.0 $g.L^{-1}$), and temperatures (30 – 50 °C) to elucidate adsorption mechanisms. Equilibrium data were analysed using Langmuir and Freundlich isotherm models, while kinetic behaviour was evaluated through pseudo-first-order, pseudo-second-order, and intraparticle diffusion models to identify rate-limiting steps. Preliminary studies reveal a maximum adsorption capacity of pellets up to 833 mg. g^{-1} for CIP removal. This work clearly establishes structure–transport–performance relationships for binder-engineered biochar pellets and demonstrates their potential as scalable adsorbents for pharmaceutical removal from water.

Keywords: Adsorbents; biochar; pharmaceutical removal

Study of Biochar and Metal Organic Framework (MOF) composites for removal of Heavy Metals from Rural Household Sewage Streams

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Abstract

In majority of the rural areas, untreated household sewage is often discharged straight onto agricultural land or local water bodies. This leads to long-term accumulation of heavy metals and degradation of soil health. A modular treatment column comprising of low-cost Biochar-Metal Organic Framework (MOF) composite was prepared and experimented for removal of heavy metals from such rural household sewage. Biochar was synthesized from locally sourced sugarcane stubs. MOF–biochar composites were prepared via in-situ growth of a metal organic framework on the biochar surface. Batch and continuous experiments were conducted in glass columns using simulated wastewater mimicking rural household sewage. Optimum ratio of MOF: Biochar for the maximum adsorption efficiency and the optimum residence time was determined. Adsorbent composites were characterized for surface area and porosity using Brunauer-Emmett-Teller (BET) analysis, crystallinity using X-Ray diffraction technique and morphology using scanning electron microscopy. Characterization revealed that MOF functionalization significantly increased specific surface area and availability of active binding sites compared to unmodified biochar. These properties lead to enhanced adsorption capacity and faster uptake of heavy metals, when subjected to both batch and continuous column operation. The findings in this study provide a framework for designing a low-cost treatment system in rural ecosystems.

Keywords: Metal Organic Framework (MOF), Household sewage, Biochar, Adsorption, Heavy metals

A Metal-Free g-C3N4 Fluorescent ON/OFF Sensor for Paraquat Detection in Wastewater via Fe2+/Ascorbic Acid Modulation

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Abstract

The extensive use of agrochemicals has raised serious concerns regarding environmental safety. The agricultural run-off led to accumulation of agrochemicals in waste water bodies and these chemicals have adverse effect on human health when ingested. Therefore, the early detection of such toxic chemicals is essential to protect both the environment and human health. The present study explores the potential of g-C3N4 as an ON/OFF fluorometric sensor for the detection of paraquat using Fe2+ and ascorbic acid. g-C3N4 emerges as a promising candidate due to its metal-free nature, visible-light activity, moderate band gap (2.6-2.8 eV), and excellent physical and chemical stability. g-C3N4 was synthesized via the thermal polymerization method using thiourea as a precursor at 550 °C for 4 h with a heating rate of 10 °C min-1. Its optical, morphological, and structural properties were characterized using X-ray diffraction (XRD), field-emission scanning electron microscopy (FE-SEM), Fourier transform infrared spectroscopy (FTIR), diffuse reflectance spectroscopy (DRS), and photoluminescence (PL) spectroscopy. The fluorescence emission of the g C3N4 solution was quenched in the presence of Fe2+ and subsequently recovered upon the addition of ascorbic acid, with excitation at 350 nm and emission observed at 800 nm. Overall, this study demonstrates the potential of g-C3N4 as an effective fluorescence based sensor for paraquat detection in wastewater and river streams.

Keywords: Graphitic carbon nitride, Paraquat sensing, Fluorescent, Quenching, wastewater, agrochemicals

Experimental Analysis of Industrial Wastewater Treatment using Natural Adsorbents

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Abstract

The rapid population increase and unsustainable urbanization have intensified the exploitation of water resources, which has increased freshwater demand and resulted in the extensive water pollution. Improper discharge of wastewater by industrial, agricultural and domestic sources which releases dyes, toxic heavy metals and organic pollutants, are persistent and toxic to living systems. Wastewater must be treated effectively to avoid ecological degradation and safeguard the health of the people. The traditional methods of treatment are usually linked to high costs of operation and high energy consumption. Natural adsorbents like orange peel, pomegranate peel, rice husk, coconut shell, and other agricultural residues have become more and more popular as a sustainable alternative since they are environmentally compatible and economical. The adsorption process facilitates the attachment of pollutants onto the adsorbent surface through physical and chemical interactions. Factors such as adsorbent composition, alkalinity, thermal conditions, and level of contaminant present influences adsorption performance. The wastewater sample used in this study was originated during the production of Reactive Black 5 (4-amino-5-hydroxy-3,6-bis[[4-(2-sulfonatooxyethylsulfonyl)phenyl]diazenyl]naphthalene-2,7-disulfonate), a common reactive azo dye widely employed in textile industries. It has near-neutral pH (6-8), ambient temperature, and high organic pollution with chemical oxygen demand of 5000-8000 mg/L and biological oxygen demand of 2000-4000 mg/L. The treatment method focuses on the minimization of pollutants and reuse of in-process water based on the concept of reduce, reuse, and recycle (3R's) to reduce freshwater usage. The results show that the dye wastewater contains a lot of organic matter and thus it needs advanced treatment method to be treated effectively to remove the pollutants. Sodium hypochlorite (NaOCl) pre-treatment was used to for the reduction of color and then natural adsorbents such as coconut shell ash, pomegranate peel, sugarcane bagasse coated with moringa seeds, and corn cob ash were prepared and applied to wastewater treatment, and their performance was assessed by analytical methods such as UV- Vis spectrophotometry, particle size analysis, and FTIR spectroscopy.

Keywords: Wastewater Treatment, Natural adsorbents, Reactive Black 5, NaOCl, Adsorption efficiency

Biomass Torrefaction for Sustainable Low-Carbon Energy Systems

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Abstract:

The transition to low-carbon and hydrogen-integrated energy systems requires sustainable solid bioenergy carriers that can complement emerging clean fuel technologies while utilizing existing thermal infrastructure. Biomass torrefaction has emerged as a promising thermochemical upgrading process for converting low-grade lignocellulosic biomass into energy-dense, hydrophobic, and coal-compatible solid fuels. The aim of this study is to critically synthesize recent advances in torrefaction technology (2020-2025) and to quantitatively assess reactor performance, energy density behavior, lifecycle emissions, and hydrogen-integration potential within an integrated assessment framework. Unlike previous reviews that separately addressed reactor design, fuel properties, or environmental impacts, this work integrates techno-economic indicators, life cycle assessment (LCA) findings, torrefaction severity impacts, and hydrogen pathway compatibility to identify deployment readiness and key research gaps. Torrefaction is carried out at 200-300°C under inert or oxygen-limited conditions, where dehydration, decarboxylation and depolymerization reactions mainly decompose hemicellulose and partially reform cellulose and lignin. These reactions increase the carbon-to-oxygen (C/O) atomic ratio after torrefaction from approximately 0.6-0.8 (raw biomass) to 1.0-1.3, which increases fuel quality and coal-like behavior. The higher heating value increases from 15-18 MJ/kg to 20-23 MJ/kg, while the equilibrium moisture absorption decreases from 10-15% to 2-5%. Typical mass and energy yields range from 60-80% and 75-90%, respectively, resulting in an energy density ratio of 1.2-1.4. A comparative evaluation of fixed-bed, rotary drum, fluidized-bed, and microwave-assisted reactors is presented using performance indicators such as heat transfer efficiency, specific energy consumption, scalability, and process controllability. Rotary drum and fluidized-bed systems demonstrate industrial scalability with process efficiencies reaching 85–90% when heat integration is implemented, while microwave-assisted systems offer rapid volumetric heating and reduced residence times but face scale-up challenges. Characterization techniques including thermogravimetric analysis (TGA), Fourier transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM), and elemental analysis confirm structural reorganization, oxygen reduction, aromatic carbon enrichment, and improved combustion stability. From an application perspective, torrefied biomass enables 20-50% coal substitution in co-firing systems, improves the grindability index and gasification reactivity, and enhances syngas quality by reducing tar formation in downstream hydrogen production pathways and increasing the H_2/CO ratio. Life cycle assessment studies indicate that greenhouse gas emissions are reduced by 60-90% compared to coal-based systems, depending on the feedstock source, transport distance, and system boundaries. Techno-economic analyses suggest that decentralized torrefaction units with integrated heat recovery can achieve competitive production costs under optimized supply-chain conditions; however, challenges related to feedstock heterogeneity, reactor temperature uniformity, standardization of torrefied fuel properties, and large-scale logistics remain significant barriers. Overall, the findings suggest that biomass torrefaction has significant potential as a bridging technology connecting traditional solid fuels with hydrogen-compatible and low-carbon energy systems, while further advances in reactor optimization, quality standardization, and integrated process design are required for large-scale commercialization.

Keywords: Biomass Torrefaction; Bio-coal; Renewable Energy; Thermochemical Conversion; Energy Densification; Hydrogen Integration

Diffusion-Controlled Silver Metal Recovery from Acidic Aqueous Photovoltaic Recycling Effluents for Photonic Applications

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Abstract
Electrochemical recovery of contaminants and valuable resources from industrial wastewater is a critical need for sustainability and circular economy. This is particularly relevant for photovoltaic (PV) recycling effluents, where metal-laden leachates pose environmental risks to water bodies if untreated. Recent high-efficiency electrowinning processes achieved >98% recovery rates with reduced CO_2 emissions [1, 2]. This study presents a potentiostatic electrochemical method for selective silver extraction and re-deposition from end-of-life solar panel recycling effluents. Silver was selectively leached from PV panel using dilute nitric acid, generating an Ag^+-rich aqueous electrolyte that simulates metal-contaminated industrial wastewater. This leachate was then treated via potentiostatic chronoamperometry at ~0.84 V on fluorine-doped tin oxide (FTO) glass substrates. The current-time transient exhibited an initial spike (~0.34 mA), rapid decay, and steady-state current (~0.03-0.04 mA), reflecting double-layer charging, nucleation, and diffusion-limited growth, aligning with recent advances in controlled electro-crystallization for wastewater remediation. Scanning electron microscopy (SEM) image revealed anisotropic, island-like silver deposits with broad particle size distribution, confirming effective ion reduction and morphology consistent with diffusion-controlled processes. The deposits comprise nanorods/nanoplates with widths in the range of 40-100 nm. UV-Visible spectroscopy measurement shows a plasmonic absorption near ~380 nm consistent with the transverse localized surface plasmon resonance (LSPR) mode of silver nanostructures. The combined optical-structural evidence confirms plasmonically active Ag nanostructures formed via electrodeposition from the PV recycling effluents.

Keywords: Photovoltaic recycling effluent; Electrochemical recovery; Silver electrodeposition; Potentiostatic chronoamperometry; Plasmonic silver nanostructures
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Synthesis and characterization of polyaniline for the remediation of chromium from aqueous solution

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Abstract:
The current water crisis necessitates the development of new materials for wastewater treatment. A variety of nanomaterials are continuously being investigated for their potential as adsorbents for environmental remediation. Researchers are exploring ways to develop low-cost, simple, and sustainable materials for removal of pollutants. Polyaniline, a polymer synthesized from aniline, shows significant promise as a solution for mitigating water pollution. Polyaniline is one of the most promising conducting polymers due to its environmental stability, low cost, and tunable physicochemical properties. In this study, polyaniline was synthesized via chemical oxidative polymerization of aniline under acidic conditions and evaluated for its potential for remediation of chromium-contaminated water. The synthesized polyaniline was characterized using Fourier Transform Infrared Spectroscopy (FTIR), X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM), Brunauer-Emmett-Teller (BET), and UV–Visible spectroscopy to confirm its structural, morphological, and optical properties. Batch adsorption experiments were conducted to evaluate the efficiency of polyaniline for removing hexavalent chromium [Cr(VI)] from aqueous solutions. The effects of pH, contact time, initial chromium concentration, and adsorbent dosage were systematically investigated. Results demonstrated that polyaniline exhibits high affinity toward Cr(VI), primarily through electrostatic interactions and redox reactions. This study focuses on the various aspects of polyaniline, including its sources, preparation methods, mechanism, wastewater treatment applications, and regeneration.

Keywords: wastewater, Polymerization, Chromium, Adsorption, Remediation

Waste-to-Resource: Enhanced Performance and Cost-Efficiency of Coal Fly Ash-Derived Zeolite for Water Remediation

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Abstract

Zeolite Y is an important aluminosilicate material widely used in catalysis, adsorption, and ion exchange applications due to its high surface area and well-defined microporous structure. Conventionally, zeolite Y is synthesized via hydrothermal routes using pure chemical reagents such as sodium aluminate and sodium silicate. Although this synthetic approach allows precise control over composition and crystallinity it suffers from several limitations including high production cost, high energy consumption, large crystallization time, and the use of non renewable and environmentally unfriendly raw materials. Additionally, the disposal of alkaline waste streams generated during synthesis raises concerns regarding environmental sustainability. In contrast, the synthesis of zeolite Y from coal fly ash (CFA), an abundant industrial by product of thermal power plants, offers a cost-effective and environmentally friendly alternative. CFA serves as a rich source of alumina and silica, eliminating the need for expensive chemical precursors while simultaneously addressing waste management issue. Zeolite Y derived from CFA has managed to exhibit comparable or improved physiochemical properties such as high crystallinity, suitable Si/Al ratio, enhanced surface area, and better ion exchange and adsorption capacity. Furthermore, the presence of inherent microporosity and structural defects in CFA-based zeolite Y often improves mass transfer and adsorption performance for dyes removal. Overall, the utilization of CFA for zeolite Y synthesis not only reduces production cost and environmental impact but also promotes sustainable material development through waste valorization.

Keywords: Zeolite; adsorption; waste management

Track 5 - Technologies and Innovations for the Management of Water Resources

Water Management Innovations In Swimming Pools: Health, Hygiene, And Performance Implications For Athletes

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Abstract:

This study investigates the impact of water management innovations in swimming pools on athletes' health, hygiene standards, physical comfort, and performance efficiency. With increasing concern for athlete welfare and safe sports infrastructure, modern water management practices such as advanced filtration systems, improved disinfection methods, and balanced water quality have gained importance. The research adopts a quantitative, survey-based approach to examine athletes' perceptions of water cleanliness, hygiene, comfort, and training outcomes. Multivariate regression analysis, one-way ANOVA, and Pearson correlation techniques were used to test the proposed hypotheses. The findings reveal that water management innovation variables explain only a limited proportion of variation in athletes' satisfaction with health and hygiene standards. Age-based differences in health and comfort perceptions were also found to be statistically insignificant. Additionally, no significant relationship was observed between water quality factors and athletes' performance efficiency. Overall, the study concludes that while water management innovations are essential for maintaining safety and hygiene, their direct statistical impact on athlete satisfaction, comfort, and performance remains limited within the scope of this research.

Keywords: Water management innovations, swimming pools, water quality, hygiene standards, athlete health, performance enhancement, filtration systems, disinfection technologies, sports infrastructure.

Geochemical Prospectivity and Hydrochemical Characterization of the Rajgir Geothermal System, Eastern India

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Abstract:
The Rajgir geothermal system in Bihar, eastern India, represents a low-enthalpy non-volcanic geothermal resource situated within the tectonically active Rajgir-Munger metasedimentary belt of the Munger-Saharsa Ridge zone. Despite the presence of several thermal manifestations geothermal systems along the eastern India margin remain underexplored. This study presents an integrated geochemical and hydrochemical assessment of the Rajgir hot springs to evaluate their geothermal prospectivity and suitability for sustainable utilisation. Seven geothermal springs evolving along fault-controlled zones at the foothills of the Rajgir hills were systematically sampled and analysed. Measured surface temperatures range from 45 to 50°C, with near-neutral pH (6.1-6.5), low electrical conductivity (60-75 µS/cm) and low TDS (40-45 mg/L) indicating weak mineralisation and shallow circulation depths. Major ion chemistry reveals a dominant Ca-Mg-HCO_3 hydrochemical facies as confirmed by Durov classifications, reflecting carbonate dissolution and rock-water interaction as the primary geochemical processes. Irrigation suitability indices including Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC) and Irrigation Water Quality Index (IWQI) classify the waters within the C1-S1 field of the Wilcox diagram, indicating excellent suitability for agricultural use with low salinity and sodium hazards. Water Quality Index (WQI) values further confirm that the geothermal waters are safe for domestic applications. The geochemical signatures suggest a fault-mediated hydrothermal system dominated by locally recharged groundwater heated by subsurface geothermal gradients rather than deep magmatic inputs. This study establishes the first comprehensive geochemical baseline for the Rajgir geothermal system and highlights its potential for sustainable domestic, agricultural, and low-enthalpy geothermal applications. The findings contribute to a broader understanding of structurally controlled geothermal systems in eastern India and provide a scientific foundation for future geothermal exploration and resource management in similar non-volcanic tectonic settings.

Keywords: Hydrogeochemical modelling, Geochemical characterisation, Sustainability, Prospective resources

Hydrogeochemical Controls on Uranium Occurrence in Groundwater: Implications for Safe Drinking Water Management

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Abstract
Uranium contamination in groundwater has emerged as a critical water quality concern in many regions, particularly within semi arid aquifer systems where groundwater constitutes the primary source of drinking water. Elevated uranium concentrations are often governed by complex hydrogeochemical processes rather than lithological uranium abundance alone, complicating prediction, monitoring, and mitigation efforts. A process-based understanding of uranium mobilization is therefore essential for effective groundwater quality management and protection of public health. This study investigates the hydrogeochemical controls on uranium occurrence in groundwater using an integrated analytical framework. Groundwater samples are being analyzed for alkalinity, major ions, trace elements, dissolved inorganic carbon (DIC), stable water isotopes ($\delta^{18}O$-$\delta^{2}H$), radiocarbon (^{14}C-DIC), and uranium isotopes ($^{234}U/^{238}U$). These parameters are used to evaluate water-rock interaction processes, redox conditions, carbonate complexation, groundwater residence time and recharge characteristics that collectively influence uranium mobility and distribution within aquifer systems. The combined use of isotopic and chemical tracers enables discrimination between geogenic controls and process-driven enrichment mechanisms. The findings of this work are expected to identify hydrogeochemical settings vulnerable to uranium enrichment and to provide a scientific basis for risk-based groundwater management. By linking fundamental geochemical processes with water quality implications, the study supports informed decision-making for monitoring strategies and selection of appropriate mitigation and treatment options for uranium-affected drinking water sources, contributing to sustainable water resource management. A total of 36 groundwater samples were collected from three locations in Gujarat: Ahmedabad (22.1352° N, 71.8951° E), Vadodara (22.2724° N, 73.6878° E), and Patan (23.6435° N, 71.1004° E). Preliminary investigations included in-situ measurements of physicochemical parameters (pH, oxidation-reduction potential, electrical conductivity, resistivity, total dissolved solids, salinity, and temperature), along with laboratory analyses of major ions and trace elements, including uranium. The results of these analyses will be presented and discussed during the presentation.

Keywords: Uranium contamination; Hydrogeochemical controls; Uranium mobilization; Water-rock interaction; Isotopic tracers; Groundwater quality

Indigenous Rainwater Harvesting and Groundwater Storage Practices in Ahmedabad Pols: Lessons for Sustainable Urban Water Management

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Abstract
Rapid urbanisation has created challenges related to groundwater depletion and contamination in Indian cities. This sometimes gets aggravated by centralised water distribution systems and ageing pipeline infrastructure. Recent incidents of sewage–water mixing in cities such as Indore and Gandhinagar highlight the vulnerability of modern supply networks and the urgent need for resilient, decentralised and indegenous water management approaches. This paper examines indigenous rainwater harvesting and groundwater storage systems within the heritage pol houses of Ahmedabad, Gujarat. For centuries, these heritage homes have incorporated underground tanks, recharge wells, and carefully designed catchment surfaces that allow effective rainwater capture, natural filtration, and long-term groundwater preservation. Field observations and community accounts indicate that water stored through these systems has remained usable and uncontaminated across generations, even during increasing urban density. The study is backed by our field documentation of selected pol houses, supported by semi-structured interviews with local residents, caretakers, and community elders to understand system design, maintenance practices, and patterns of collective stewardship. By analysing these indigenous practices, the paper demonstrates how decentralised, locally managed infrastructure can enhance water quality, reduce dependence on vulnerable pipeline-based supply, and support sustainable groundwater recharge. The study proposes that integrating indigenous water harvesting knowledge into modern urban planning at a community scale can support government initiatives, improve water security, and offer scalable solutions for rapidly growing cities. Such hybrid approaches can play a crucial role in advancing sustainable water treatment and management strategies in urban India.

Keywords: Indigenous Water Management; Rainwater Harvesting; Community Practice

Comparative Analysis of Water Quality and Seasonal Variability in Three Major Rivers of Malappuram District, India

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Abstract

Water is vital for human health, ecosystems, and environmental sustainability, yet its quality is increasingly threatened by human activities and natural contaminants. Rivers, essential for drinking water, irrigation, and hydropower, face degradation from urban, industrial, and domestic discharges, as well as basin geology and climatic factors. In India, nearly 80% of water bodies are polluted, and in Kerala—particularly Malappuram district—dense population, waste disposal, land-use changes, and fertiliser use have intensified river pollution, further amplified by fluctuating hydrological conditions. This analysis focused on assessing pollution levels, seasonal changes, and the comparative water quality of the Bharathapuzha, Chaliyar, and Kadalundi rivers situated in the Malappuram district of Kerala. Monthly samples were collected from March 2019 to February 2025. The study involved the analysis of physico-chemical and bacteriological parameters, which were evaluated against Indian drinking water standards, assessed by using the Weighted Arithmetic Water Quality Index and Nemerow's Pollution Index. Excellent water quality (WQI < 25) was noted in Bharathapuzha in January 2020 (12.4), in Chaliyar in March 2019 (23.0) and May 2023 (20.3), as well as in Kadalundi in March 2019 (21.0) and January 2020 (20.0). Satisfactory water quality (WQI 26–50) was documented in Bharathapuzha in March 2023 (37.9), May 2023 (39.6), and July 2023 (36.9), along with Chaliyar in January 2020 (28.5), February 2020 (33.7), January 2021 (37.3), and March 2023 (37.3). In all other months and seasons, the WQI values were found to be poor to unsuitable for use across all three rivers. The results of this research offer significant insights for governmental bodies, water management organizations, and various stakeholders in developing effective strategies aimed at protecting and enhancing surface water quality for public utilization. The findings highlight the critical need for long-term, integrated river management plans that are supported by ongoing monitoring and timely interventions to ensure the sustainable protection of the Bharathapuzha, Chaliyar, and Kadalundi rivers in Malappuram District, Kerala, India. This analysis encompassed both physicochemical parameters of these rivers, with sampling conducted monthly from March 2019 (the onset of pre-monsoon) to February 2025 (the conclusion of post-monsoon). In the case of Bharathapuzha and Chaliyar, samples were gathered from four distinct locations each, while five locations were sampled in Kadalundi. The samples collected underwent testing for various water quality parameters following standard procedures. From these findings, ten physicochemical parameters were analyzed in accordance with IS 10500: 2012 set by BIS, to determine their suitability for drinking purposes. A comparative analysis of the rivers was conducted, alongside an examination of the special and seasonal variations in PRM, SWM, NEM, and POM regarding river water quality. Subsequently, the water quality and the degree of pollution were assessed using WAWQI, and the contribution of each parameter to pollution was identified through the Nemerow single factor pollution index method. The Water Quality Index (WQI) values for the Bharathapuzha, Chaliyar, and Kadalundi rivers predominantly surpassed 100 throughout the majority of the study period, classifying the water as unsuitable for use and signifying the necessity for proper treatment before any human consumption or domestic application. The monthly average WQI values for all three rivers consistently remained above 100, with the only exception being the Kadalundi River in March, which underscores the ongoing deterioration of water quality. Seasonally, WQI values were significantly elevated during the Southwest Monsoon (SWM), followed by the Northeast Monsoon (NEM), indicating the impact of monsoonal runoff and increased pollutant influx. Overall, the Bharathapuzha River displayed a highly unsatisfactory water quality condition, the Chaliyar River indicated a severely poor and alarming status, and the Kadalundi River demonstrated a notable decline in quality. In conclusion, the water quality of all three rivers can be described as severely poor and unfit for both domestic and industrial use, highlighting the urgent requirement for effective management and treatment strategies. The analysis of seasonal variations aimed to assess the impact of both monsoon and non monsoon periods on the physicochemical and bacteriological properties of river water. This assessment reflects the interplay of climatic factors—most notably rainfall intensity and distribution—alongside land use practices and human activities within the respective river catchments. The monsoon seasons, particularly the Southwest and Northeast Monsoons, were marked by increased turbidity, occasional rise in iron, intermittent rise in BOD, and elevated COD levels, largely due to intensified surface runoff, soil erosion, and the movement of suspended solids and organic matter into the rivers. Conversely, the pre- and post-monsoon periods typically showed heightened concentrations of TDS, total hardness, and chloride, attributed to diminished dilution, extended residence times, and increased mineral dissolution. Dissolved oxygen levels remained fairly consistent throughout the seasons, with a minor decrease noted during the pre-monsoon period. However, ongoing bacteriological contamination suggested a persistent anthropogenic impact, regardless of seasonal fluctuations. Collectively, these seasonal trends underscore the significant influence of monsoonal rainfall on river water quality, shaped by catchment-specific land use and human interventions.

Keywords: Bharathapuzha; Chaliyar; Kadalundi; physicochemical parameters; WAWQI; seasonal trends.

Track 6 - Challenges and Opportunities: Wastewater Treatment

Multi-Metric Performance Evaluation of Gridded Soil Moisture Models for Sustainable Agricultural Water Management in a Semi-Arid Region of India

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Abstract
Accurate assessment of soil moisture is essential for monitoring agricultural drought, particularly reliable soil moisture information is fundamental to sustainable water management, agricultural drought monitoring, and climate-resilient planning in semi-arid regions experiencing increasing hydro climatic variability. This study evaluates the performance of three widely used gridded soil moisture products—ERA5-Land, FLDAS (Noah LSM), and GLDAS—against ISRO's satellite-derived soil moisture dataset, which exhibits 92% agreement with in-situ observations. The assessment is conducted over the Saurashtra region of Gujarat, India, a predominantly semi-arid and water-stressed agricultural zone where efficient water allocation and drought preparedness are critical for sustainable development.
All datasets were harmonized to a common spatial resolution using Inverse Distance Weighting (IDW), and performance was evaluated for the period 2016–2024 using multiple statistical metrics, including RMSE, bias, correlation, Jensen–Shannon divergence, normalized mean absolute error (NMAE), and a multi-criteria TOPSIS ranking approach. Results demonstrate that GLDAS consistently outperforms the other products, showing the lowest error measures, minimal distributional divergence, and the strongest correspondence with ISRO observations. ERA5-Land exhibits moderate performance with relatively low bias but higher uncertainty in distributional characteristics, while FLDAS shows the weakest agreement across all metrics.

The findings underscore the suitability of GLDAS for operational drought monitoring, irrigation scheduling, and sustainable agricultural water management in semi-arid environments. By improving the reliability of soil moisture estimates, this study supports evidence-based water governance and contributes to the implementation of the Sustainable Development Goals, particularly SDG 2 (Zero Hunger), SDG 6 (Clean Water and Sanitation), and SDG 13 (Climate Action).

Keywords: Gridded Soil moisture data; Agricultural drought; Semi-arid region; Remote Sensing and reanalysis datasets; Model performance evaluation, Water governance and planning, Agricultural water sustainability

Future Trends in Water Security Using Rainwater Harvesting Techniques

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Abstract
Day by day, the population in cities is increasing, and consequently, the demand for drinking water is also rising. In the long term, decentralised water distribution or individual water storage systems can be more sustainable. Tubewells are relatively easy to construct and are economically affordable; however, uncontrolled extraction has led to a continuous decline in groundwater levels. In this context, rainwater harvesting (RWH) at the individual household level emerges as a viable option for ensuring future water security. Rooftop rainwater collection is an effective solution to reduce urban water scarcity and mitigate flooding problems. Promotion of the rainwater harvesting technique can partially control urban flooding while simultaneously providing potable water to households using RWH systems. Moreover, it ensures water availability during lean periods and contributes to groundwater recharge, thereby raising the groundwater table, which has been declining due to chaotic groundwater extraction for drinking purposes. In this paper, a few case studies from Vadodara city have been presented, where residents face high costs of potable water, seasonal non-availability of water, deterioration in water quality (colour and odour), and low groundwater levels. These problems are partially solved by using the RWH system. From these cases, it is found that people have individual underground sources of water, and in the future, this may be easy due to developing technology. In most of the implemented RWH systems, the "Reverse Y-flow" technique has been adopted along with a two-stage filtration system using a 200-micron mechanical filter. In severe cases, a separate underground storage tank has been constructed specifically for drinking water purposes to ensure long-term water security.
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Keywords: Rain Water Harvesting; Tube well; Reverse Y-flow; Mechanical filter; Water Security

Weaving Water Conservation Messages: A Reception Analysis of Selected Indian advertisements

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Abstract
While around three-fourths of the Earth's surface is covered with water, only a fraction of it is fit for human consumption, making it a precious resource essential for the survival of humankind. This fact becomes even more pertinent as the distribution of water across the globe is not equitable but rather sporadic. To make matters worse, the existing drinkable water is increasingly being contaminated due to the discharge of human and industrial waste. The severity of the situation is such that by 2030, around 700 million people might be displaced due to water shortages. Amid such a scenario, concerted efforts have been made at both global and national levels to create awareness about water conservation. The same efforts are also reflected in contemporary media platforms as well- be it cinema, newspaper, television, social media or advertisements. Among all of them, advertisement, a paid form of media content aimed at promoting a product/service/behaviour among the masses is a lucid way of not just communicating brand pitch but also messages on social issues. In fact, reputed companies across the world try to position themselves as entities who are responsible and care about the environment so as to increase their appeal, acceptability and goodwill among the masses. For this purpose, they carry out philanthropic works and communicate the same through advertisements. Not just this, even governments across the world, create public service advertisements (PSAs) so as to create awareness among the masses about water conservation and its judicious utilization. The present study is dedicated to explore the reception of advertisements in the Indian context and assess their effectiveness in generating awareness about water conservation. For this purpose, the study utilizes content analysis and personal interview methods to gather data on effectiveness of advertisements as a vehicle of promoting water conservation messages. The study will serve as a guide for future researchers who wish to understand the implications of embedding sustainability and conservation related messages in advertisements. Also, the study will provide detailed suggestions regarding the scope of improvement in existing promotion practices of water conservation utilized by government sponsored PSAs.

Keywords: Water conservation, Public service advertisements, Content Analysis, Interview, appeal, awareness

Rx5day (mm) and PR >=1.0 mm Trend Analysis of Agroclimatic Zone – II of Gujarat State

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Abstract
Agroclimatic Zone – II of Gujarat state has been considered for the research work. This zone contains 4 major districts namely Bharuch, Narmada, Surat & Tapi. An analysis of climate extremes indices was conducted for annual total wet-day rainfall when sum of daily PR>=1.0mm (PRCPTOT), maximum amount of rainfalls in 5 consecutive days (Rx5day) over the agroclimatic zone – II of Gujarat. PRCPTOT trend analysis by Sen's slope test indicates that about 7 stations (28%) show significant negative trend in June month, 5 stations (20%) showing negative trend in August month and about 12 stations (48%) show positive trend in September month. Also, about 1 station (4%) in SW Monsoon & 1 station (4%) in Annual PRCPTOT are showing positive trend. Rx5day (mm) trend analysis by Sen's slope test indicates that about 12 stations (48%) show significant negative trend in June month, 1 station (4%) showing positive trend meanwhile 2 stations (8%) showing negative trend in August month and about 6 stations (24%) show positive trend in September month. Also, about 1 station (4%) in SW Monsoon is showing positive trend and meanwhile 3 stations (12%) in SW Monsoon & 3 stations (12%) in Annual Rx5day (mm) are showing negative trend.

Keywords: *R- Software; Rainfall Anomaly Index; Agro-Climatic Zone; R-Studio; Kalman Smoothing & Arima Model*

Marigold-Mediated Removal of Toxic Heavy Metals: Mechanisms and Environmental Implications

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Abstract

Pollution of water bodies is a major environmental issue arising from industrial effluents, mining activities, and wastewater runoff, posing serious threats to ecosystems and public health. In this study, a hydroponic experiment was conducted to evaluate the phytoremediation potential of *Tagetes erecta* Linn. for the removal of iron (Fe) and zinc (Zn) from aqueous environments. The study was conducted in a greenhouse under consistent environmental conditions, enabling a precise assessment of the plant's metal uptake capacity. Marigold, an ornamental plant with rapid growth and high biomass, was deployed at various concentrations of iron and zinc (50 µg/ml, 150 µg/ml, 250 µg/ml, 350 µg/ml, and 450 µg/ml) in separate containers. The biochemical parameters in the plant were assessed using standard methods by harvesting the plants at definite time intervals (3, 6, 9, 12, and 15 days). The result shows a reduced chlorophyll, carbohydrate, and cellulose content, along with an increase in proline and phenol content shows the tolerance mechanism of the plant. The bioconcentration factor and the translocation factor are less than 1. These results demonstrated that *T. erecta* effectively absorbed significant amounts of both Fe and Zn, with metal accumulation predominantly occurring in the root tissues, indicating its potential as a rhizofiltration agent. Furthermore, the study revealed minimal signs of phytotoxicity, suggesting the plant's resilience in metal-stressed conditions. These findings highlight *T. erecta* as a promising candidate for hydroponic-based phytoremediation strategies targeting Fe and Zn contamination in wastewater or polluted aquatic systems. Phytoremediation of iron and nickel supports the UN Sustainable Development Goals by improving water quality (SDG 6), reducing health risks (SDG 3), and promoting ecosystem restoration (SDG 15) through eco-friendly, plant-based remediation. As a low-energy, green technology, it also contributes to climate action (SDG 13) by minimizing environmental impact and enhancing sustainability.

Keywords: Aquatic pollution, phytoremediation, SDGs, marigold, proline

Hybrid AI–ML Framework for Water Quality Index Prediction in Indian Rivers

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Abstract

The accurate evaluation of river water quality is important to ensure ecological health, human well-being, and sustainable use of resources in India. The traditional approach for monitoring river water quality uses periodic sampling, which restricts the ability to identify sudden changes in water quality and delays response time for mitigation. The AI-ML based framework for predicting the Water Quality Index (WQI) is developed to create reliable short-term predictions by analysing historical WQI trends from multiple Indian rivers. The hybrid regression model incorporates several types of AI-ML components, including recurrent neural models and advanced ensemble learners, in order to capture both temporal correlations and non-linear relationships in the behaviour of water quality. The model was trained on several years of WQI data collected from numerous Indian river monitoring sites and resulted in a maximum coefficient of determination ($R^2 = 0.90$) and consistently low prediction error rates. The results of this study indicate that the hybrid framework can accurately predict Water Quality Indicators (WQIs), which could be used to make decisions based on the information generated by the framework. While the current study was primarily concerned with developing and validating the model, the methodology behind the framework has significant promise as an avenue for integration with IoT sensor networks, GIS (Geographical Information Systems) platforms, and satellite observation systems, leading to the development of dashboards with the capability to perform real time monitoring and provide early warning systems. Overall, the work provides a pathway to create an advanced water quality forecasting capability for Indian river systems that has the potential for scalability and utilization on a large scale. .

Keywords: Water quality index (WQI), WQI forecasting, Indian rivers, Machine learning, Hybrid architecture

Enhancing Urban Water Treatment Governance Using IoT-Driven Monitoring Systems

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Abstract:
Public health and sustainable urban development hinge on the accessibility of safe and reliable drinking water for all members of the community. Urban Local Bodies (ULBs) within India are responsible for ensuring the safety of drinking water through CPHEEO Regulations (Centre for Public Health Engineering and Environment, a national agency) and BIS IS:10500 (Indian Standard drinking water). ULBs should be taking charge of improving infrastructure development for national missions such as AMRUT 2.0 (Scheme for Urban Infrastructure Development) and Smart Cities Mission but challenges remain such as ageing water pipelines, unreliable supply, and lack of effective monitoring of water quality in real time. Systematic assessments of urban drinking water quality show significant gaps in the required systematic surveillance of drinking water supplied by cities and that many cities have been impacted by contamination events due to delayed detection of how safe the drinking water from that city is (identified through traditional manual sampling of water and laboratory testing). Within this context; this paper proposes an Internet of Things (IoT)-based monitoring framework that assesses the availability and safety of drinking water through continuous oversight of the data (monitoring) to better support ULBs with respect to strongest water governance in their respective cities. The proposed framework uses an array of distributed sensors to monitor drinking water quality at both the water treatment plant and throughout the city's water distribution network by measuring such key Drinking Water Quality (DWQ) indicators as pH, turbidity, water temperature, dissolved oxygen (DO), and total dissolved solids (TDS). The sensors monitor variables in real time by combining edge-computing and data analytics in the cloud to enable the generation of real-time alerts, detection of anomalies, and predictive analytics. Furthermore, by enabling real-time monitoring (compared to just periodic sampling), the framework will facilitate improved and faster decision-making, enhance regulatory compliance, and improve the transparency of the water-quality decision-making process by providing mobile dashboards and public displays. The study argues that embedding IoT technologies within existing governance structures can significantly reduce health risks, improve operational efficiency, and move cities closer to achieving Sustainable Development Goal 6.

Keywords: water quality; Monitoring; operational efficiency

Hydrogen Production from Seawater and Wastewater: Advancements and Challenges

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Abstract
Production of hydrogen using alternate sources of water such as seawater and municipal wastewater is turning out to be a promising opportunity as it will reduce our dependence on purified fresh water which is already scarce in nature. These water resources are abundant and readily available in the nature, hence offering significant potential but challenges such as chloride induced corrosion, catalyst degradation, and competing chlorine evolution reactions limit its efficiency and durability. There has been a change over time in the design of the catalyst that has resulted in improving the reaction selectivity and the efficiency of the hydrogen evolution reaction.
In addition, direct production of hydrogen with high energy efficiency and reduced energy consumption has been made possible using municipal waste water by innovative system configurations such as forward osmosis integrated alkaline electrolysis. Moreover, membrane assisted and modular electrolysis systems have proven to be more scalable and stable in operation. Despite these developments, issues with long-term durability, cost reduction, and widespread use still exist. The efficiency, scalability, and sustainable production of hydrogen from alternative water sources depends on the ongoing development of corrosion-resistant materials, advanced membranes and integrated system designs. This paper reviews latest developments and existing challenges in electrolysis of seawater and wastewater.

Keywords: desalination; reverse osmosis, batch reverse osmosis, water treatment, multi-effect distillation

Applied Machine Learning to Predict Water Safety

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Abstract
It seems extraordinary that the water that supports all terrestrial, as well as aquatic, life on our planet is so scarce. Only about 0.3 percent of our freshwater is found in the surface water. More than 99 percent of Earth's water is unusable by humans and many other living things. In India only 18 Blue flag beaches are available despite having one of the largest coastlines the world. Religious activities and gatherings caried out near or for sacred water bodies lead to pilgrims getting affected with water borne diseases. To help in prediction of safety such important water bodies, the study focusses on applying Machine learning models like Random Forest and incorporate data preprocessing techniques like MICE (Multiple Imputation by Chained Equations) to deal with missing values in the dataset containing very important features. The research also has focused on the limitations of less data availability by applying Active Learning to get optimal results to predict water safety.

Keywords: Machine Learning, Active Learning, Water safety, Random Forest, MICE

Pilot-Scale Study of Electrocoagulation for Recycling Metal Cleaning Effluent: Removal of Surfactants, Heavy Metals, suspended colloids and Turbidity

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Abstract

This Study represents a pilot scale assembly of electrocoagulation unit, trial and evaluation for treatment of effluent generated from metal cleaning process. (Contain metallic ions. surfactants and suspended particles/colloids). It is very difficult to treat such effluent by normal treatment process such as coagulation, filtration and biological treatment. There for we developed a suitable electrocoagulation process for the treatment for this effluent. The process involves the removal of heavy metals by applying an electrical current of 125 A and 12 V (DC) through multiple aluminium and iron electrodes.This EC process results in the breakdown of organic compounds, surfactants and the removal of heavy metals and colloids/turbidity/suspended solids . The effluent COD (Chemical Oxygen Demand) And BOD (Biochemical Oxygen Demand) were rejected above 95%. The metal ions rejection was above 98% and turbidity rejection above 99%. The unit has a treatment capacity of 100 L with an operating time of 3h. The pilot plant operated at a power consumption of 1.5 KW/H. The process of electro-coagulation was further followed by filtration. Based on the pilot study results it can be assured that electrocoagulation can be a viable method for the effective treatment of complex industrial waste water.

Keywords: Electro-coagulation; Turbidity; Surfactants; Suspended solids; Heavy metals.

Data-Driven Climate Forecasting for Water Resource Planning in Gujarat

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Abstract

Reliable long-term forecasting of temperature and precipitation is fundamental to sustainable water resource planning, irrigation management, and drought preparedness in climate-sensitive regions. This study presents a comparative machine learning ensemble framework for regional climate forecasting in Gujarat, India, a state where agriculture and water availability are critically dependent on the southwest monsoon. ERA5-Land daily reanalysis data spanning 1980 to 2025 was used to train and evaluate five models, namely SARIMA, Prophet, LSTM, Random Forest, and XGBoost, using an 80-20 chronological train-test split and four performance metrics: RMSE, MAE, MAPE, and R^2. Historical analysis revealed a warming trend of +0.045°C per decade and a positive precipitation trend of +8.2 mm per year over the 45-year study period, with rainfall strongly concentrated within the June to September monsoon window. Random Forest achieved the highest accuracy for temperature forecasting with R^2 of 0.960 and RMSE of 0.746°C, while SARIMA performed best for precipitation with R^2 of 0.698 and RMSE of 60.27 mm. Future projections through 2050 suggest continued warming and sustained monsoon seasonality, with widening uncertainty beyond 2035. The results demonstrate that variable-specific model selection within an ensemble framework significantly improves forecast reliability, offering water managers and policymakers a practical, reproducible tool for long-term climate-informed water planning in Gujarat and comparable regions across India.

Keywords: water resource management; climate forecasting; machine learning ensemble; SARIMA; long-term projection.

Bayesian and Probabilistic Safety Analysis of Groundwater Contamination Risk in Uranium Open-Pit Mines

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Abstract

The risk for possible radioisotope contamination of groundwater is assessed in the context of a probabilistic safety assessment. Using an Event Tree analysis, the total scenario and probable results of the insitu leaching of radionuclides from any near surface nuclear facility by rainwater which is further utilized as drinking water by critical groups surrounding the pit is to be evaluated. Such an evaluation can be performed by creating programs computationally to calculate essential metrics as the rate of radioactive release, the concentration of radionuclides in groundwater, the dose consumed by members, and the overall danger related to each radioisotope. This paper outlines the necessary density functions of failure for risk assessment. The redundancy functions of the barrier systems that are established against any hazard are the initial factors. To determine the likely release rate of each radionuclide into groundwater, the facility's radioactive concentrations must be computed. Radioisotope concentration variation in groundwater is additionally speculated to be influenced by concentration depletion with spatiotemporal variance. By utilizing the ingestion dose coefficient for each isotope determined by the International Atomic Energy Agency [IAEA], we can calculate the radiation dose to humans through this pathway based on the concentration of radionuclides in groundwater when consumed at a rate of 2.2 litres per day. The International Commission on Radiological Protection multiplies the radiation dose consumed by individuals of the critical group by the risk factor for fatal or non-cancerous diseases and critical hereditary effects to complete the final risk assessment.

Keywords: Probabilistic Assessment; Radionuclides Safety; Event tree analysis; Groundwater Contamination; Spatio-temporal variation.

Bayesian artificial neural network for Probabilistic Safety Analysis of Pressurised water reactor

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Abstract

Probabilistic Safety Analysis (PSA) is an essential methodology for evaluating the risk and reliability of nuclear power plants, particularly for complex systems such as Pressurised Water Reactors (PWRs). Traditional PSA methods rely heavily on fault trees, event trees, and deterministic models, which often face limitations in capturing nonlinear dependencies and uncertainties present in real reactor systems. In recent years, Artificial Neural Networks (ANNs) have emerged as powerful tools for modelling complex relationships in large datasets. However, conventional ANN approaches typically provide point estimates and lack a systematic mechanism to quantify uncertainty, which is crucial in safety-critical applications such as nuclear reactor analysis. To address this limitation, Bayesian Artificial Neural Networks (BANNs) offer a robust probabilistic framework by incorporating Bayesian inference into neural network modelling. This study explores the application of Bayesian Artificial Neural Networks for the Probabilistic Safety Analysis of Pressurised Water Reactors. The proposed approach integrates probabilistic learning with neural network architectures to model complex system behaviour and estimate the likelihood of different failure scenarios under uncertain conditions. By treating network weights as probability distributions rather than fixed values, the Bayesian framework enables the quantification of epistemic and aleatory uncertainties inherent in nuclear system operations. The model can learn from historical operational data, simulated accident scenarios, and system parameters to predict risk measures such as core damage frequency and system reliability.

Furthermore, the Bayesian framework enhances the interpretability and robustness of neural network predictions by providing confidence intervals and probabilistic outputs, which are highly valuable for decision-making in nuclear safety management. The results demonstrate that Bayesian neural networks can effectively capture nonlinear interactions among reactor subsystems and improve the accuracy of risk predictions compared to conventional PSA techniques. The proposed methodology can support risk-informed decision-making, improve safety assessment procedures, and contribute to the development of advanced intelligent tools for nuclear reactor safety evaluation.

Keywords: Probabilistic Safety Analysis, Bayesian Artificial Neural Network, Pressurised Water Reactor, Nuclear Reactor Safety, Uncertainty Quantification, Machine Learning in Nuclear Engineering.

Concept Design Of Energy Efficient Module For Total Suspended Solids Removal From Influent Using Combination Of Clarifier And Sand Media Filter

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Abstract

This paper presents a concept design for an integrated, energy-efficient module specifically engineered for the removal of Total Suspended Solids (TSS) from wastewater influent. Conventional TSS removal often relies on energy-intensive filtration or chemical-heavy processes; however, this design utilizes a synergistic combination of a primary clarifier and a sand media filter. The module leverages gravity-driven flow to facilitate initial sedimentation in the clarifier, significantly reducing the solids loading before the influent enters the sand filtration stage. This dual-stage approach prevents media clogging and reduces the frequency of energy-consuming backwash cycles. Theoretical design parameters suggest that this hybrid configuration can achieve desired TSS removal efficiency while maintaining a lower energy consumption and area footprint compared to conventional systems. The study outlines the unique arrangement of lamella clarifier and Automatic Valveless Gravity Filter (AVGF). Placement of compact modular clarifier above the AVGF reduces the space requirement while clarifier act as a feed tank for AVGF and gravity flow ensures no separate pump is needed. This unique compact design saves the space and very less energy consumption due to pumping energy reduction. Valve less design of AVGF requires eventually no operational manpower so operation cost of overall system will be reduced.

Keywords: AVGF; Lamella clarifier; Total Suspended Solids; Effluent; Wastewater Treatment Plant; Sand Media Filter

Centre of Excellence in Water Treatment and Management

Centre of excellence in Water is established at PDEU in association of grant received from DST and DBT through different projects. This includes “Low Cost - Renewable Energy Driven (LC-RED) Water Treatment Solutions Centre”; (https://lc-red.wixsite.com/lcred) funded by Department of Science and Technology under "Water Technology Initiative”, and “bIo-mimetic and Phyto-technologies designed for low-cost purification and recycling of water (INDIA-H_2O)”; (www.india-h2o.eu) funded by Department of Biotechnology. Objective of COE in Water at PDEU is to develop, design and demonstrate high-recovery low-cost water treatment systems for saline groundwater and for domestic and industrial wastewaters. The focus for developments will be in the arid state of Gujarat, where surface water resources are very scarce. Cost-effective technologies and systems are proposed with the aim of lowering energy costs through dramatic improvements in energy efficiency, new bio-based approaches to water recycling, and use of renewable energy. Reject waste streams will be minimized or reduced to zero, thus protecting the environment.

Advanced membrane processes, including biomimetic FO and RO and layer-by-layer assembly of ultra/ nano-filtration membranes, will be developed and combined to provide new methods of purifying water from saline groundwater and from municipal and industrial wastewaters, providing water that is safe for drinking or suitable for irrigation. They will be implemented in cost-effective modes in systems incorporating phytoremediation and complementary processes.

Low-cost sensors for real-time monitoring of the key parameters important for efficient operation of membrane processes will be integrated with monitoring and management systems to ease maintenance of performance and ensure sustainability of these systems which have previously suffered from a lack of robust and reliable operational data, leading to frequent early failure and redundancy. The remote monitoring will also make possible collection of data to enable knowledge to be built up about long term performance, feeding into decision support tools for design and operation.

Systems will be developed and integrated to TRL6 as advanced prototypes that will be integrated with renewable energy sources under real operational conditions in the arid and industrialised state of Gujarat, with prospective applications in many other water-stressed and salinized areas such as Rajasthan, Punjab and Tamil Nadu. The development of business models will maximise the use of indigenous supply chains to reduce costs and ensure sustained implementation of the technologies.

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