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TECHNOLOGICAL INNOVATIONS IN CHEMICAL ENGINEERING TOWARDS SUSTAINABILITY

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The Department of Chemical Engineering came into existence in the year 1994 with the B.Tech programme. The Department has highly qualified and experienced faculty with modern infrastructural facilities. The department offers B.Tech, M.Tech, and Ph.D programmes in Chemical Engineering. The B.Tech Chemical Engineering programme is accredited by the National Board of Accreditation (NBA) till June 2028. The IIChE- SVCE Student chapter has been bestowed with the best Student Chapter Award of Ambuja and Pidilite Industries award 17 times. The department organizes a National Level Technical Symposium “PANSOPHY” every year and also organizes Short Term Training Programs / Faculty Development Programs / Seminars / Workshops / Guest Lectures / Certificate Courses, and National / International Conferences periodically. Three patents and projects from various funding agencies, viz. BRNS, TNSCST, AICTE - MODROBS, AICTE - RPS, IIChE have been granted to our faculty and students to enhance their research and technical skills.

ABOUT TIChSCON’26

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CONTENTS

Production of Biodegradable Plastic Using Cassava Starch

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ABSTRACT

The extensive use of conventional petroleum-based plastics has resulted in serious environmental problems due to their non-biodegradable nature, leading to soil, water, and marine pollution. To overcome these challenges, the development of biodegradable and eco-friendly alternatives from renewable resources has gained significant attention. In this project, biodegradable plastic is synthesized using cassava (Kesava) starch, which is an inexpensive, renewable, biodegradable, and abundantly available natural polymer. The biodegradable plastic is prepared by gelatinizing cassava starch in water, followed by the addition of glycerin as a plasticizer to improve flexibility and mechanical properties. The resulting viscous solution is cast into thin films and dried at room temperature to obtain biodegradable plastic sheets. The prepared bioplastic films exhibit good transparency, flexibility, and film-forming ability. The study also highlights the effect of plasticizer concentration on the physical properties of the bioplastic. The synthesized biodegradable plastic demonstrates potential applications in packaging, agriculture, and disposable products. This simple, low-cost, and environmentally friendly method offers a promising approach for reducing dependence on petroleum-based plastics and contributes toward sustainable material development and environmental protection.

Keywords: Biodegradable Plastic; Cassava Starch; Gelatinization ; Sustainable Material Development; Environmental Protection.

SYNTHESIS AND DFT STUDIES OF (2Z)-2-[2,6-di (furan-2-yl)-1-hydroxy-3- isopropylpiperidin-4-ylidene] HYDRAZINE-1-CARBOXAMIDE

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ABSTRACT

In this study, the (2Z)-2-[2,6-di(furan-2-yl)-1-hydroxy-3 -isopropylpiperidin-4-ylidene] hydrazine 1-carboxamide was synthesized and characterized using spectroscopic and DFT analyses. The cyclic voltammetry method is used to determine the electrochemical properties of synthesized heterocyclic compound. The shape of the voltammetry curves and their peak potential virtually fingerprint the electrochemical reduction of the compound. Structural assignment of the product was concluded based on elemental analysis, infrared, and NMR spectroscopy with DFT. Solvent effects on UV-vis absorption were examined in the compound's higher excitation states via the TD-DFT approach. The electronic structure was characterized using AIM, LOL, and ELF topological analyses, while reactivity and biological potential were assessed through MEP, FMO, NLO, NBO, and Fukui functions. Finally, the compound's therapeutic profile was validated through molecular docking.

Keywords: Cyclic Voltammetry; Molecular Docking; Fukui Function; DFT.

Experimental and Theoretical Investigation of Piperidinium 4-Nitrophenolate Single Crystals for Nonlinear Optical Applications

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ABSTRACT

Piperidinium p-nitrophenolate (PPNP) was synthesized by reacting piperidine and p-nitrophenol in a 1:1 molar ratio. The required amount of p-nitrophenol was first dissolved in methanol, and piperidine was added dropwise with continuous stirring. After stirring for about 6 h, a clear homogeneous solution was obtained. The solution was then allowed to undergo slow evaporation, leading to the formation of spontaneously nucleated crystals. The synthesized compound was purified through repeated recrystallization using methanol and used for crystal growth. The synthesis scheme of the PPNP compound is shown in Figure 1.

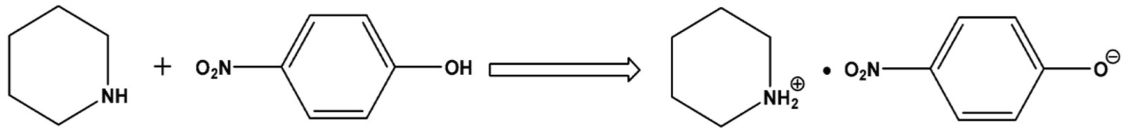

Figure 1. Synthesis scheme for PPNP compound

A theoretical study of piperidinium 4-nitrophenolate (PPNP) was carried out using Density Functional Theory (DFT). The molecular geometry, vibrational spectra (FTIR and FT-Raman), frontier molecular orbitals, molecular electrostatic potential, dipole moment, polarizability, and first hyperpolarizability were also calculated. The results provide insight into the structural, spectroscopic, and nonlinear optical properties of PPNP, indicating its potential for nonlinear optical device applications.

Keywords: Solution Growth; IR and Raman; NLO Studies; DFT Studies; Molecular Electrostatic Potential.

Production of Bioplastic Using Chitosan Extracted from Lobster Shells

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ABSTRACT

The extensive use of conventional petroleum -based plastics has resulted in serious environmental problems due to their non-biodegradable nature leading to soil, water and marine pollution. To overcome these challenges, the development of biodegradable and eco-friendly alternative from renewable sources is need of the hour. In this project, biodegradable plastic is produced using chitosan extracted from lobster shells. This is waste to value source renewable, biodegradable and abundantly available natural polymer. Bioplastic was prepared using extracted Chitosan as the main raw material. Initially, chitosan was taken and mixed with vinegar (acetic acid) to dissolve it completely and form a homogeneous solution. The mixture was then heated using the double-boiling method until it developed a thick gel-like consistency. After achieving the desired texture, the gel was poured into a mold of the required shape. Finally, the molded material was kept under sunlight for about two days to dry and solidify into a biodegradable bioplastic film. The prepared bioplastic exhibits transparency, flexibility, good film forming ability and easily biodegradable. The final bioplastic film has potential applicants and reduces the dependence on conventional plastics The bioplastic prepared from chitosan extracted from lobster shells exhibits properties such as biocompatibility, antimicrobial activity, and biofertilizer potential. Due to its antimicrobial nature, it can be used in food packaging to prevent microbial contamination. Its biocompatibility makes it suitable for biomedical applications like wound dressing. Additionally, its biofertilizer property allows its use in agricultural applications to support plant growth. Therefore, chitosan-based bioplastics can serve as a sustainable alternative to conventional plastics.

Keywords: Chitosan Biopolymer; Biodegradable Polymer Film; Marine Waste Valorisation; Biocompatible Material; Antimicrobial Bioplastic.

Mycelium Bricks with PCM Coatings

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ABSTRACT

The growing demand for sustainable alternatives in the construction industry has significantly increased interest in bio-fabricated composites derived from fungal mycelium. Mycelium, exhibiting remarkable natural binding properties, can be cultivated on lignocellulosic agricultural wastes such as sawdust, rice husk, coconut coir, banana stem fibres, and sugarcane bagasse. These materials enable the formation of lightweight, biodegradable structures that can effectively replace conventional, non-renewable construction components. By integrating microencapsulated paraffin wax as phase change materials (PCMs), these innovative hybrid bricks function as dynamic thermal buffers, providing "living insulation" capable of storing and releasing energy through latent heat. This unique property allows the bricks to passively moderate indoor temperatures, reducing reliance on mechanical heating and cooling systems and responding adaptively to fluctuations in environmental conditions. Mycelial development was closely monitored under carefully controlled laboratory conditions, with key parameters including temperature (20°C– 30°C), humidity (70%–90%), pH (5.5–6.5), and aeration varied systematically to assess their impact on growth kinetics. These precisely regulated conditions promoted optimal mycelial colonization and the formation of high-quality bio-based composites. This study thoroughly investigates the fabrication process, thermal kinetics, and performance of these smart, eco-friendly bricks, demonstrating their potential as sustainable, climate-responsive building components. By uniting mycelium's biodegradable matrix with PCMs' latent heat storage capability, this work paves the way for next-generation architecture that adapts dynamically to environmental changes, reduces energy consumption, and promotes greener built environments.

Keywords: Mycelium Composites; Phase Change Materials; Dynamic Thermal Insulation; Sustainable Construction; Climate-Responsive Architecture.

Sustainable Removal of Heavy Metals from Wastewater Using Bio-Derived Carbonaceous Adsorbent Addressing Responsible Waste Management

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ABSTRACT

The presence of heavy metals in industrial wastewater has become a major environmental concern due to their toxicity, persistence, and ability to accumulate in living organisms. Chromium is one of the most hazardous heavy metals commonly discharged from industries such as electroplating, leather tanning, dye manufacturing, and metal finishing. If not properly treated, chromium-contaminated wastewater can cause serious environmental pollution and health risks. Therefore, developing sustainable and cost-effective methods for the removal of heavy metals from wastewater is essential. This study focuses on the sustainable removal of chromium from wastewater using biochar derived from ash gourd (Benincasa hispida). Ash gourd, an abundant agricultural waste material, was utilised as a precursor for biochar production through thermal treatment. The prepared biochar was employed as an eco-friendly and low-cost adsorbent for chromium removal from aqueous solutions. Various characterisation techniques were used to analyse the structural and surface properties of the prepared biochar, which are important factors influencing adsorption performance. Batch adsorption studies were conducted to evaluate the efficiency of ash gourd biochar in removing chromium from wastewater. The results indicate that the biochar exhibits promising adsorption capacity due to its porous structure, high surface area, and the presence of active functional groups on its surface. These characteristics enhance the interaction between chromium ions and the biochar surface, facilitating effective adsorption. The use of ash gourd-derived biochar not only provides an efficient solution for heavy metal removal but also promotes the utilisation of agricultural waste for environmental applications. Overall, this study demonstrates that ash gourd biochar can serve as a sustainable, low-cost, and environmentally friendly adsorbent for chromium removal from wastewater, contributing to improved water treatment and waste valorisation practices.

Keywords: Biochar; Ash Gourd (Benincasa hispida); Chromium Removal; Heavy Metal Adsorption; Wastewater Treatment; Sustainable Adsorbent; Agro-Waste Utilisation.

Green Synthesis of Silver Nanoparticles Using Plant Extracts: Characterization And Antimicrobial Studies

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ABSTRACT

The increasing demand for environmentally sustainable nanomaterials has led to the development of green synthesis approaches that eliminate the use of hazardous chemicals. In this study, silver nanoparticles (AgNPs) were synthesized using plant extracts such as neem (Azadirachta indica) and green tea, which act as both reducing and stabilizing agents due to the presence of bioactive compounds including polyphenols, flavonoids, and terpenoids. The synthesis was carried out under ambient conditions, making the process simple, cost-effective, and energy efficient. The formation of AgNPs was initially confirmed by a visible color change from pale yellow to dark brown, indicating the reduction of silver ions (Ag+) to metallic silver (Ag^{o}), and further validated using UV–Visible spectroscopy, which exhibited a characteristic surface plasmon resonance (SPR) peak in the range of 400–450 nm. Fourier Transform Infrared (FTIR) analysis revealed the presence of functional groups such as –OH, –C=O, and –NH, confirming the role of plant biomolecules in the reduction and stabilization of nanoparticles. The antimicrobial activity of the synthesized AgNPs was evaluated against Gram-positive (Staphylococcus aureus) and Gram-negative (Escherichia coli) bacteria using the agar well diffusion method, and the results demonstrated a clear concentration dependent increase in antibacterial activity, with higher concentrations showing enhanced zones of inhibition comparable to standard antibiotics such as ampicillin and vancomycin. This antibacterial effect is attributed to the interaction of nanoparticles with bacterial cell membranes, leading to structural damage and disruption of cellular functions. Further characterization studies using Scanning Electron Microscopy (SEM) are in progress to determine particle morphology and size distribution, while photoluminescence studies are being conducted to analyze optical properties, and photocatalytic dye degradation experiments are underway to evaluate the environmental remediation potential of the synthesized nanoparticles. Overall, this study demonstrates that plant-mediated synthesis of silver nanoparticles is a sustainable and efficient approach for producing stable nanomaterials with significant antimicrobial and catalytic properties, highlighting their potential applications in biomedical, pharmaceutical, and environmental areas.

Keywords: Green Synthesis; Silver Nanoparticles; Plant Extracts; UV–Visible.

Process-Intensified Extraction of Piperine from Piper Nigrum using Hydrotrope-Assisted Techniques

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ABSTRACT

Piperine, the principal bioactive alkaloid present in Piper nigrum, is widely utilized in pharmaceutical and nutraceutical industries due to its bioavailability-enhancing and therapeutic properties. However, conventional extraction techniques for piperine rely heavily on organic solvents, require prolonged extraction times, and involve high energy consumption, making them inefficient and environmentally unsustainable. Therefore, there is a growing need to develop alternative extraction strategies that are both efficient and aligned with green chemistry principles. In this study, a process-intensified hydrotrope-assisted extraction approach is proposed for the efficient recovery of piperine. Hydrotropes enhance the solubility of poorly water-soluble compounds in aqueous media without the formation of micelles, thereby reducing the dependence on organic solvents. Sodium benzoate is selected as the hydrotrope based on its solubilization efficiency, availability, and environmental compatibility. The study involves a comparative evaluation of three extraction techniques, namely hydrotrope-assisted hydrothermal extraction, ultrasound-assisted hydrotrope extraction, and microwave-assisted hydrotrope extraction. A systematic experimental design is developed by varying key parameters such as temperature, extraction time, hydrotrope concentration, and solid-to-solvent ratio. The selected techniques are evaluated based on extraction yield, process efficiency, and energy considerations. Ultrasound assisted extraction is expected to enhance mass transfer through cavitation, while microwave assisted extraction is anticipated to provide rapid and efficient extraction due to volumetric heating. The proposed approach aims to identify an optimized and sustainable extraction method for piperine. The study contributes to the development of green extraction technologies and provides a framework for integrating hydrotropy with process intensification techniques for bioactive compound recovery.

Keywords: Piperine; Hydrotropy; Process Intensification; Ultrasound Extraction; Microwave Extraction

Removal of Rhodamine Dye from Aqueous Solution using Coconut Shell Biochar: A Batch Adsorption Study

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ABSTRACT

The increasing discharge of dye-containing effluents from textile and allied industries poses a significant environmental concern due to their toxicity, persistence, and resistance to conventional treatment methods. Among these, Rhodamine dyes are widely used and are known for their potential ecological and health impacts. This study investigates the adsorption performance of coconut shell-derived biochar as a low-cost and sustainable adsorbent for the removal of Rhodamine dye from aqueous solutions. Biochar was synthesized via controlled thermal carbonization and subsequently characterized to evaluate its surface properties and functional groups. Batch adsorption experiments were conducted to examine the influence of key operational parameters, including contact time, initial dye concentration, adsorbent dosage, and solution pH. The adsorption process was analyzed to determine equilibrium behavior and removal efficiency. The results demonstrated that the biochar exhibits appreciable adsorption capacity toward Rhodamine dye, attributed to the presence of surface functional groups and developed porous structure. The study highlights the potential of utilizing agricultural waste-derived biochar as an effective and environmentally friendly adsorbent for dye removal applications. This work provides insights into sustainable wastewater treatment strategies while supporting the valorization of biomass waste.

Keywords: Biochar; Adsorption; Coconut Shell Waste; Wastewater Treatment; Dye Removal; Sustainable Adsorbent

Integration of Advanced Oxidation Processes as a Pre-Treatment Strategy for Enhanced Bio-Removal of Microplastics in Aquatic Environments

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ABSTRACT

The increasing prevalence of microplastics (MPs) in aquatic environments has emerged as a critical environmental concern due to their persistence, resistance to degradation, and potential for bioaccumulation within food chains. Conventional wastewater treatment systems often exhibit limited efficiency in the complete removal of MPs, resulting in their continuous discharge into natural water bodies. To address this limitation, this study proposes a synergistic treatment framework that integrates Advanced Oxidation Processes (AOPs) as a pre-treatment stage to enhance subsequent biological removal mechanisms. The AOP stage facilitates the generation of highly reactive species, particularly hydroxyl radicals, which induce oxidative degradation and physicochemical modification of microplastics. These transformations include surface oxidation, polymer chain scission, increased hydrophilicity, and reduced electrostatic repulsion, thereby decreasing the recalcitrance of the particles. As a result, the modified microplastics exhibit improved interaction with microbial communities, biofilms, and sludge-based systems, enhancing their retention and potential biodegradation in the secondary biological treatment stage. A bench-scale system was employed to evaluate the influence of key operational parameters governing the transition from chemical oxidation to biological entrapment. The findings indicate that the integrated AOP–biological approach significantly improves overall removal efficiency compared to standalone processes. This study demonstrates a sustainable strategy for improving effluent quality and provides insight to mitigate the environmental impact of microplastic pollution in aquatic systems.

Keywords: Microplastics; Advanced Oxidation Processes; Hydroxyl radicals; Biological Treatment.

Predictive Thermal Management of Ev Battery Packs: A Matlab/Simulink Study on Hybrid Nitrogen-Based Safety Systems

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ABSTRACT

As Electric Vehicle (EV) battery packs are increasingly subjected to ultra-fast 5C charging protocols, the thermal lag inherent in traditional reactive cooling systems poses a significant risk of localized hotspots and thermal runaway. This study presents a comprehensive MATLAB/Simulink-based simulation framework for an advanced Battery Thermal Management System (BTMS) that integrates passive phase-change materials (PCM) with a predictive nitrogen-based fire suppression unit. Moving beyond static threshold-based triggers, this work develops a Model Predictive Control (MPC) algorithm capable of forecasting cell temperature trajectories by analyzing real-time current, voltage, and internal resistance transients. The simulation environment utilizes a high-fidelity electro- thermal model to simulate heat generation and dissipation across a multi-cell pack. The simulation results indicate that the predictive control logic anticipates thermal anomalies up to 60 seconds in advance, allowing for pre-emptive nitrogen deployment that reduces peak temperature overshoot by 14.5% compared to conventional thermostat-based systems. Furthermore, the study evaluates a Pulse Width Modulation (PWM) strategy for gas release, demonstrating a 20% improvement in suppressant efficiency while maintaining oxygen concentrations below the 5% combustion limit. By quantifying the reduction in thermal gradients ($\Delta T < 1.5$ °C) and the acceleration of heat dissipation through predictive airflow-PCM synergy, this simulation-based research provides a robust theoretical foundation for the design of fail-prevent safety architectures. The findings highlight the critical role of algorithmic intelligence in enhancing the safety and operational lifespan of high-energy-density lithium-ion battery systems.

Keywords: Battery Thermal Management System; Electric Vehicles; MATLAB; Fire Suppression System; Phase-Change Materials.

Molecular Mechanisms and Emerging Technologies for Microplastic Removal and Degradation

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ABSTRACT

The pervasive accumulation of microplastics (<5 mm) in global ecosystems poses a significant environmental and public health threat due to their persistence, toxicity, and ability to transport contaminants. This review analyses the molecular mechanisms underlying four major strategies for eliminating microplastics: chemical technologies, photocatalytic degradation, biodegradation, and hybrid membrane systems. Chemical methods are categorised into removal processes (e.g.coagulation, agglomeration, froth flotation) and degradation processes (e.g., advanced oxidation, hydrolysis). The study further examines molecular pathways, including reactive oxygen species in photocatalysis and enzymatic activity in biodegradation. Performance, technological readiness levels (TRL), and commercialisation potential of these approaches are evaluated. While chemical removal and hybrid systems (such as membrane bioreactors) demonstrate high efficiency, photocatalytic and biological methods remain limited by slow degradation rates and incomplete mineralisation. The review identifies key research gaps, emphasising the need for deeper molecular-level understanding, development of synergistic approaches (e.g., plasmonic photocatalysis), and scalable, high efficiency technologies to address the growing challenge of microplastic pollution.

Keywords: Microplastics; Biodegradation; Hybrid Membrane System; Sustainable Water Treatment.

Electrolyte Engineering and Optimization Strategies in Vanadium Redox Flow Batteries

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ABSTRACT

The vanadium redox flow battery (VRFB) has emerged as a promising large-scale energy storage system due to its long cycle life, inherent safety, and flexible architecture that allows independent scaling of power and energy capacity. However, its widespread commercialization is constrained by the physicochemical limitations of the vanadium electrolyte, which governs the energy density, thermal stability, ionic conductivity, and overall electrochemical performance of the system. Conventional sulfuric acid-based electrolytes are restricted by vanadium solubility limits (≤ 2.0 M), precipitation of V(*V*) species at elevated temperatures, and increased viscosity at higher concentrations, resulting in reduced efficiency and operational instability. This project focuses on the systematic optimization of electrolyte chemistry for enhancing the performance of vanadium redox flow batteries. A mixed-acid electrolyte system comprising varying molar ratios of sulfuric acid and hydrochloric acid is developed to improve vanadium ion solubility beyond 2.5 M while expanding the operational temperature window. The physicochemical properties—including ionic conductivity, viscosity, density, and thermal stability—are investigated across a temperature range of 0°C to 55°C. Electrochemical characterization is performed using cyclic voltammetry, electrochemical impedance spectroscopy, and galvanostatic charge–discharge analysis to evaluate kinetics, overpotential behaviour, and capacity retention. By correlating electrolyte composition with electrochemical performance and mass transfer characteristics, this study aims to establish a balanced formulation that enhances energy density while maintaining thermal stability and high round-trip efficiency. The outcome of this research seeks to provide a scalable electrolyte optimization strategy for advancing VRFB technology toward sustainable grid-scale energy storage applications.

Keywords: Vanadium Redox Flow Battery; Vanadium Electrolyte; Solubility; Stability; Electrochemical Analysis

Optimization Studies in Atmospheric Distillation Unit Using Meta-Heuristic Algorithms

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ABSTRACT

Crude oil atmospheric distillation is the primary separation process in petroleum refineries, responsible for fractionating crude into valuable products such as heavy naphtha, kerosene, diesel, and atmospheric gas oil (AGO). The performance of the Atmospheric Distillation Unit (ADU) significantly influences downstream processing efficiency, energy consumption, and refinery profitability. This study presents a comparative multi-objective optimization of product yields in an ADU using rigorous Aspen plus simulation integrated with three evolutionary algorithms: Non-dominated Sorting Genetic Algorithm-II (NSGA-II), Multi-Objective Particle Swarm Optimization (MOPSO), and Multi-Objective Differential Evolution (MODE). A detailed steady- state simulation model of the ADU was developed using the BK10 thermodynamic package, incorporating crude assay characterization, side strippers, pump-arounds, and reflux operations. Key operational variables including Steam flowrate, distillate rate, pump- around duties, and stripping steam rates were selected as decision variables. The optimization objectives were to maximize valuable product yields (heavy naphtha, kerosene, diesel, and AGO) while minimizing energy consumption and operational trade- offs. Pareto-optimal fronts generated by NSGA-II, MOPSO, and MODE were compared based on convergence behavior, diversity preservation, and computational robustness. Results demonstrate that evolutionary multi-objective techniques effectively handle the highly nonlinear and constrained nature of ADU operations. Among the methods evaluated, NSGA-II exhibited superior stability in maintaining solution diversity, while MOPSO showed faster convergence characteristics. The comparative framework provides a systematic decision-support tool for refinery engineers to identify optimal operating conditions under conflicting economic and operational objectives.

Keywords: Atmospheric Distillation Unit; Multi-Objective Optimization; NSGA-II; MOPSO; MODE.

Design of Debutanizer Column for Polyisobutylene Separation with Parametric Optimization of the Reboiling System – A Review

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ABSTRACT

Polyisobutylene (PIB) is a vital industrial polymer, prized for its chemical stability and viscosity in applications ranging from lubricants to adhesives. However, its commercial value depends on high-purity separation from light hydrocarbons—a process that centers on the efficiency of the debutanizer column. This review examines the engineering design of these columns, specifically focusing on how reboiler optimization drives thermal performance and product quality. The study evaluates standard industrial practices, comparing traditional manual methodologies like Kern's Method with modern computational process simulations. By analyzing the interplay between vapor-liquid equilibrium and hardware selection—such as tray vs. packing configurations—this paper highlights the technical trade-offs required in PIB processing. Central to this discussion is the parametric optimization of the reboiler; we explore how adjusting shell diameter, baffle spacing, and tube arrangements can maximize heat transfer while strictly managing pressure drop and energy use. Beyond design, the review addresses the practical hurdles of handling high-viscosity polymer streams, including the management of fouling and high-intensity energy demands. Safety remains a critical pillar, with a focus on pressure relief, grounding for flammable hydrocarbons, and thermal insulation. Ultimately, this review demonstrates that precise tuning of reboiler operating conditions is the most effective way to improve separation efficiency and reduce long-term maintenance costs in petrochemical plants.

Keyword: Polyisobutylene; Debutanizer Column Unit; Pump; Reboiler Unit; Optimization.

Sustainable Recovery of Lithium from Spent Lithium-Ion Batteries Using Ultrasonically Surface-Modified Delonix Regia Bioadsorbent

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ABSTRACT

The rapid expansion of portable electronics, electric vehicles, and energy storage systems has significantly increased the consumption of Lithium-ion (Li-ion) batteries, leading to the accumulation of hazardous battery waste containing valuable and potentially toxic metals such as lithium, cobalt, nickel, and manganese. Improper disposal of these batteries can result in environmental contamination and health risks due to the leaching of heavy metals into soil and groundwater. At the same time, these metals are critical resources widely used in advanced energy systems, catalysts, and alloy manufacturing, making their recovery both environmentally essential and economically beneficial. This project focuses on the green recovery of metals from spent Li-ion batteries using ultrasonically surface-modified Delonix regia seeds as a bioadsorbent. The biomass contains lignocellulosic structures rich in hydroxyl and carboxyl functional groups, which enhance the adsorption of metal ions. The methodology involves dismantling spent Li-ion batteries to obtain cathode materials, followed by controlled leaching to produce aqueous solutions containing Li^{+}, Co^{2+}, Ni^{2+}, and Mn^{2+} ions. Batch adsorption experiments are conducted by optimizing parameters such as pH, contact time, adsorbent dosage, and initial metal concentration. The adsorption–desorption cycle enables metal recovery and regeneration of the biosorbent for repeated use. Characterization techniques including FTIR, SEM-EDX, BET, and XRD are employed to analyze surface modifications and adsorption mechanisms. Overall, this study presents a sustainable, cost-effective, and environmentally friendly approach for recovering critical metals from Li-ion battery waste, contributing to circular economy practices and aligning with Sustainable Development Goal 12 (Responsible Consumption and Production).

Keywords: Lithium-ion Batteries; Ultrasonic Surface Modification; Critical Metal Recovery; Adsorption–Desorption

Simulation And Experimental Study Of Co2 Mineral Carbonation for Sustainable Carbon Capture

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ABSTRACT

The rapid increase in atmospheric CO_2 emissions from industrial activities and fossil fuel combustion has intensified the need for efficient and permanent carbon capture technologies. Mineral carbonation presents a sustainable sequestration pathway by converting CO_2 into thermodynamically stable carbonates such as calcium carbonates ($CaCO_3$). This project investigates an integrated experimental and simulation approach for aqueous CO_2 mineral carbonation using sodium hydroxide and calcium chloride systems. In the proposed process, CO_2 is initially absorbed in an alkaline NaOH solution to form carbonate species, which subsequently react with $CaCl_2$ to precipitate stable $CaCo_3$ while partially regenerating the salt medium. The effects of key operating parameters including CO_2 flow rate, temperature and reactant concentration are evaluated to determine their influence on carbonation efficiency and product yield. Parallel process simulation using Aspen Plus is performed to conduct mass and energy balance analysis, validate reaction pathways, and assess process feasibility. The combined approach aims to enhance reaction efficiency, optimize operational conditions and contribute towards the development of a scalable and environmentally sustainable CO_2 sequestration strategy.

Keywords: Carbon Capture, Mineral Carbonation, CO_2 Sequestration, Aspen Plus Simulation.

Sustainable Energy Production Through Microbial Fuel Cells Utilizing Organic Electrolytes

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ABSTRACT

The transition toward sustainable energy systems has driven interest in alternative technologies capable of utilizing waste resources efficiently. Microbial fuel cells (MFCs) represent an innovative approach that enables direct conversion of biodegradable organic matter into electrical energy through microbial metabolic processes. This study explores the performance of an MFC system developed using organic electrolytes and dissimilar metal electrodes. An experimental setup incorporating zinc and copper electrodes was designed to evaluate power generation using readily available organic substrates, including agricultural residues, wastewater, and soil-based materials. The system was monitored over multiple days to analyze variations in electrical output under different operating conditions. Key influencing factors such as electrolyte composition, pH levels, substrate concentration, and environmental parameters were systematically examined. The effect of adding external nutrients, such as sugar solutions, was also assessed to understand their role in enhancing microbial activity. The observations indicate that the nature of the organic substrate and operating conditions significantly impact the efficiency of electron transfer and overall power output. Supplementation with additional nutrients improved microbial performance, resulting in increased voltage and current generation. The study confirms that low-cost, waste derived materials can be effectively harnessed for decentralized energy production. This work demonstrates the potential of MFC technology as a dual-purpose solution for waste management and renewable energy generation. With further improvements in system design and operational optimization, MFCs could contribute to sustainable and environmentally responsible energy systems.

Keywords: Microbial Fuel Cell; Organic Waste Conversion; Bioenergy Production; Electrode Performance; Sustainable Technology.

Evaluation of Pem Fuel Cell Operating with Various Parameters Using Hydrogen as Fuel and Oxygen/Air as an Oxidant

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ABSTRACT

Fuel cells are emerging as viable candidates as power sources in many applications, including road vehicles, small-scale power stations and possibly even portable electronics, besides providing better environment and sustainability. Polymer electrolyte membrane (PEM) fuel cells are considered to have the highest power density of all the fuel cells. PEM fuel cell mainly consists of anode and cathode containing platinum/platinum alloy electro catalyst and Nafion membrane as the electrolyte. The present paper addresses the in-house single PEM fuel cell performance operated at various operating temperatures, back pressure effects with oxygen/air as an oxidant and active area on the performance and stability of the single cell. Based on these investigations, the optimum conditions for attaining high performance are operating at higher pressure and elevated temperature with humidified reactant gases. The possible reasons are behind the higher performance of PEM fuel cells discussed in detail. The single cell appear to have been a good starting point for research, because this approach allows one to concentrate on specific problems instead of attempting to design the whole stack.

Keywords: PEM Fuel Cells; Operating Temperature; Back Pressure; Current Density.

Comparative Study of Jacketed Evaporators and Conventional Evaporation Systems for RO Reject Water Treatment: Design, Maintenance, and Energy Analysis

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ABSTRACT

The management of RO reject water has become a significant challenge in industrial wastewater treatment due to its high concentration of dissolved salts and limited disposal options. Reverse osmosis (RO), commonly applied to pre-treated water, produces purified water along with a concentrated RO reject water stream that requires further treatment. This paper presents a comprehensive review of evaporation-based methods for treating RO reject water, based on an analysis of approximately 100 research studies. Thermal evaporation plays a key role in reducing volume and enabling zero liquid discharge (ZLD) in industrial applications. Conventional evaporation systems such as multi-effect evaporators (MEE), forced circulation evaporators, and mechanical vapor recompression (MVR) systems are widely used due to their high efficiency and ability to handle high salinity streams. These systems utilize multi-stage operation and vapor reuse to reduce steam consumption. However, they are associated with high capital and operating costs, complex design, and the need for skilled operation. Additionally, issues such as scaling, fouling, and frequent maintenance increase operational difficulty and reduce long-term efficiency. In comparison, the conventional jacketed evaporator offers a simple and cost-effective alternative, particularly for small-scale or decentralized applications. Although it has lower heat transfer efficiency and higher specific steam consumption due to the absence of heat recovery, it is easier to design, operate, and maintain. This review compares jacketed evaporators with conventional systems in terms of design, maintenance, operational complexity, and steam requirement. The findings indicate a need for improved low-cost systems, and suggest that modifications such as agitation, vacuum operation, and basic heat recovery can enhance the performance of jacketed evaporators while maintaining simplicity.

Keywords: RO Reject Water, Jacketed Evaporator, Thermal Evaporation, Multi-Effect Evaporator (MEE), Zero Liquid Discharge (ZLD)

Sustainable Process Development of LABSA Production and Energy Integration Using UNISIM Simulation

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ABSTRACT

Linear Alkylbenzene Sulfonic Acid (LABSA) is one of the most widely used anionic surfactants in the detergent industry due to its excellent cleaning efficiency and biodegradability. Industrial production of LABSA involves the sulfonation of Linear Alkylbenzene (LAB) with sulfur trioxide (SO_3), which is a highly exothermic reaction requiring effective thermal management. In this study, a sustainable process flowsheet for LABSA production was developed using the UNISIM Design process simulator. The industrial falling film sulfonation reactor was approximated using a Plug Flow Reactor (PFR) model with second-order reaction kinetics. Simulation results showed that the reactor achieved a LAB conversion of 96.93% with a reactor outlet temperature of 69.69 °C. The sulfonation reaction generated 1.821×10^5 kJ/h of heat, which was removed by the reactor cooling system operating at 50.6 kW thermal duty. A shell-and-tube heat exchanger was integrated into the process to recover part of this heat and preheat the LAB feed from 25°C to 45 °C, requiring 9.352×10^3 kJ/h of heat transfer. The results demonstrate that integrating heat recovery with the sulfonation reactor improves the energy efficiency of the process and reduces the requirement for external heating utilities. The developed flowsheet provides a technically feasible and energy-efficient configuration for sustainable detergent manufacturing.

Keywords: LABSA; Sulfonation; Plug Flow Reactor; UNISIM Design; Heat Integration; Energy Recovery.

AI-Based Intelligent Traffic Management System for Urban Congestion Reduction

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ABSTRACT

Traffic congestion has become a major issue in rapidly growing urban areas, mainly due to the increasing number of vehicles and limitations in existing road infrastructure. Traditional traffic management methods often fail to respond effectively to real-time conditions, leading to delays, fuel wastage, and increased pollution. This paper focuses on the use of Intelligent Transportation Systems (ITS) combined with Artificial Intelligence (AI) to improve traffic management in urban environments. The proposed approach makes use of real-time data collected from sensors, cameras, and connected devices to monitor traffic conditions. Based on this data, AI algorithms can analyze traffic patterns and adjust signal timings dynamically to reduce congestion and improve traffic flow. The study also discusses the basic architecture of such systems, including data collection, communication, and decision-making processes. In addition, the potential benefits such as reduced travel time, lower fuel consumption, and improved road efficiency are highlighted. Some practical challenges like implementation cost, data accuracy, and system integration are also considered. Overall, the study shows that AI-based traffic management systems can provide a more efficient and adaptive solution to urban traffic problems, contributing to smarter and more sustainable cities.

Keywords: Artificial Intelligence(AI); Intelligent Transportation Systems(ITS); Traffic Management; Urban Congestion; Adaptive Traffic Signal Control.

Environmental Fate and Health Implications of Aquatic Endocrine Disrupting Chemicals

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ABSTRACT

Endocrine Disrupting Chemicals (EDCs) have gained attention in recent years due to their harmful impacts on wildlife and human health, largely caused by disruption of the endocrine system. These contaminants represent an increasing environmental problem since they can be found in a variety of aquatic environments, including surface water, groundwater, runoff, wastewater, and landfill leachate. The need to remove EDCs from water sources is more important than ever, particularly given growing populations and depleting freshwater reserves. Their distinct physicochemical characteristics and the features of various wastewater types have a major role in the effectiveness of EDC removal. The efficacy of various removal technologies, such as physical, chemical, and biological approaches, depends heavily on the technique chosen, which is determined by thorough wastewater chemical profiling. The long-term effects of EDCs on the male and female reproductive systems are a major concern. This review addresses novel concerns like the occurrence of genes that confer resistance to antibiotics during treatment procedures and recommends a thorough analysis of existing EDC removal techniques in aquatic environments. To maintain environmental balance and protect public health, these issues must be addressed.

Keywords: Aquatic Environment; Endocrine-Disrupting Compounds; Health Risks; Long-Term Effects; Pollutant Removal

Thermal Performance Enhancement of Solar Flat Plate Collector with Reflector and Phase Change Material

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ABSTRACT

The increasing demand for sustainable energy solutions has led to significant interest in improving the performance of solar thermal systems. In this study, an experimental investigation is carried out on a solar air heating system using a flat plate collector to enhance its thermal performance. The system is modified using phase change material (PCM), pebbles as thermal storage media, and an external reflector with aluminium foil to improve heat absorption. The experimental setup consists of three cases: a conventional flat plate collector, a collector integrated with paraffin wax (Grade 2) as PCM along with pebbles, and a collector combined with a reflector to increase solar radiation input. Forced convection is employed using a fan to enhance heat transfer. Temperature measurements at the inlet and outlet are recorded at regular time intervals over multiple days to evaluate system performance. The results indicate that while the conventional collector shows higher instantaneous temperature rise during peak solar hours, the PCM-integrated system exhibits improved thermal stability and sustained heat retention. The use of reflector further enhances the overall heat gain by increasing incident solar radiation. The combined effect of PCM and reflector contributes to improved energy utilization of the system. This study demonstrates that integrating thermal energy storage materials and reflectors in solar flat plate collectors can enhance performance, making them more efficient for practical air heating applications.

Keywords: Solar Flat Plate Collector; Phase Change Material; Thermal Energy Storage; Reflector; Solar Air Heater.

Development of A Sustainable Process for the Extraction of Curcumin from *Curcuma Longa* Using Ionic Liquids and Process Optimization

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ABSTRACT

Curcumin is a polyphenolic biomaterial derived from *Curcuma longa* (turmeric). It has a variety of applications, including pharmaceuticals and food processing. The conventional solvents such as ethanol, acetone, and ethyl acetate have been used for the extraction of curcumin. Although the conventional solvents possess promising characteristics such as high selectivity, abundance, stability, and yield, their inherent toxicity, energy consumption, and non-biodegradability are harmful to the ecosystem. In the past few decades, research has been progressing towards green solvents that impose less harmful impact on the ecosystem and improve process efficiency in terms of separation and economy. Hence, this study focuses on the development of a sustainable process for the extraction of curcumin using ionic liquids choline hydroxide-glycine, and choline chloride- lactic acid. The ionic liquids were synthesized, and their characteristics were studied using FTIR and XRD. The key process variables, such as solid-to-solvent ratio, extraction time, and temperature, were investigated in the range of 1:5 – 1:20, 0.5 – 4 hr, 30˚C – 60˚C, respectively, for the efficient separation of curcumin. The process modeling and optimization were performed using Response Surface Methodology (RSM) to predict the maximum yield of curcumin. The predicted values were compared with the experimental results, showing the close agreement between the predicted and experimental findings. Hence, the proposed work provides an eco-friendly and feasible alternative to conventional processes and offers a robust framework for scaling up curcumin extraction for industrial applications.

Keywords: Curcumin; Extraction; Green solvents; Ionic Liquids; Sustainable Process.

Optimized Acid Leaching for Lithium Recovery from Spent Lithium-Ion Batteries Using Ionic-Liquid Assisted Acid Leaching

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ABSTRACT

The rapid expansion in the use of lithium-ion batteries has intensified concerns regarding critical resource depletion and environmental pollution, thereby emphasizing the need for efficient and sustainable recycling technologies. This study investigates acid leaching as an effective method for lithium recovery from spent lithium-ion battery materials. The leaching process facilitates the transfer of lithium into an aqueous phase through proton-mediated reactions, enabling its separation from residual solids. In addition, alternative leaching media such as ionic liquids were explored to enhance selectivity and reduce overall chemical consumption. The key process parameters, including solvent to-feed ratio, leaching time, operating temperature, and stirring speed, were systematically examined to evaluate their influence on lithium dissolution efficiency and process performance. The results demonstrate that conventional acid leaching achieves high lithium recovery efficiencies under moderate operating conditions, while ionic-liquid-assisted systems offer improved control over metal dissolution. Overall, the findings represent a promising and environmentally sustainable strategy for lithium recovery from end-of-life lithium-ion batteries.

Keywords: Lithium-ion Battery; Lithium Recovery; Acid Leaching; Ionic Liquids; Optimization.

Numerical Simulation of Double Effect Evaporator with Reverse Feed Configuration

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ABSTRACT

This work presents the numerical simulation of a double effect evaporator with a reverse feed configuration. Such systems are widely used in chemical industries to enhance energy efficiency by reusing vapor from one effect as the heating medium for the next. In reverse feed operation, the feed enters the last effect and flows opposite to the vapor direction, making it suitable for viscous and high concentration solutions. A mathematical model based on mass and energy balances is developed for each effect. The model incorporates heat transfer, boiling point elevation, and vapor-liquid equilibrium. Numerical methods are used to solve the governing equations and predict system performance. The simulation evaluates key parameters such as temperature distribution, evaporation rate, and steam economy under varying operating conditions. Results show that the reverse feed configuration improves heat transfer efficiency and maintains a better temperature driving force, especially for concentrated feeds.

This study provides a useful tool for analyzing and optimizing evaporator performance, reducing the need for extensive experimental work, and supporting energy-efficient process design. The simulation evaluates key parameters such as temperature distribution, evaporation rate, and steam economy under varying operating conditions. Results show that the reverse feed configuration improves heat transfer efficiency and maintains a better temperature driving force, especially for concentrated feeds.

Keywords: Double Effect Evaporator; Reverse Feed Configuration; Numerical Simulation.

Process Synthesis and Multi-Objective Optimization of An Autothermal Reforming-Based Blue Ammonia Plant with Integrated Carbon Capture and Sequestration (CCS)

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ABSTRACT

The growing need for low-carbon fuels has made ammonia a top choice as a hydrogen carrier during the shift to cleaner global energy. Traditional ammonia production using Steam Methane Reforming (SMR) creates a lot of carbon emissions, so cleaner options are essential. This research designs and simulates an ammonia production process based on Autothermal Reforming (ATR) combined with carbon capture and storage (CCS), using Aspen HYSYS v11 software. It includes steps like pre reforming, ATR, water-gas shift (both high- and low-temperature), CO_2 removal, methanation, and a high-pressure ammonia synthesis loop. The Peng- Robinson equation models the thermodynamics at high pressures accurately. The ATR runs at 1030°C, converting almost all the methane into a hydrogen rich syngas with few inerts. Overall, the setup makes 1855 kmol/h (about 758 metric tons per day) of ammonia, with a single-pass conversion rate of 32.6%—better than typical industrial processes. It also captures a pure CO_2 stream of roughly 1001 kmol/h for storage. Using high- pressure synthesis at 180 bar and cryogenic separation at -40°C, the ammonia reaches about 98% purity. These findings show that ATR-based blue ammonia production is technically solid and offers great potential for low- carbon energy solutions.

Keywords: Blue Ammonia, Autothermal Reforming (ATR), Carbon Capture and Sequestration (CCS), Aspen HYSYS Simulation, Ammonia Synthesis

Eco-Friendly Enhancement of Water-Based Drilling Fluids Using Fly Ash and AI Modelling

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ABSTRACT

The present study investigates the enhancement of water-based drilling fluid (WBDF) performance using fly ash as a sustainable and eco-friendly additive, focusing on rheological properties, filtration characteristics, and AI-based predictive modelling. Drilling mud samples were prepared by varying fly ash concentration from 0 to 8 g per 350 ml of base fluid. Rheological parameters were measured using a rotational viscometer, and API filtration tests were conducted at 100 psi for 30 minutes. Experimental results show significant improvement in rheological behaviour with increasing fly ash concentration. The yield point increased from 12 to 20 lb/100 ft² (≈66%), indicating better cuttings transport. Plastic viscosity increased from 20 to 24 cP (≈20%), showing controlled internal resistance without affecting pumpability. Apparent viscosity increased from 26 to 34 cP (≈30%), improving suspension under low shear conditions. The mud exhibited non-Newtonian shear-thinning behaviour, ensuring high viscosity at low shear rates and lower viscosity at high shear rates for efficient circulation. Filtration properties also improved with fly ash addition. Filtrate volume reduced from 14 ml to 9 ml (≈36%), while mud cake thickness decreased from 2.5 mm to 1.6 mm (≈36%), indicating formation of a thin, low- permeability filter cake. AI-based regression models accurately predicted yield point and plastic viscosity with minimal deviation. The results confirm that an optimal fly ash concentration of 6–8 g/350 ml enhances drilling fluid performance while maintaining efficiency and sustainability.

Keywords: Fly Ash Valorization; Water-Based Drilling Fluid (WBDF); Rheological Characterization; Shear-Thinning Behavior; Filtration Loss Reduction; Apparent Viscosity Enhancement; Yield Point Optimization; Sustainable Drilling Additives; Non-Newtonian Fluid Mechanics; AI-based Predictive Modelling.

Green Solvent-Based and Membrane-Assisted Solvent Extraction for Sustainable Nickel Removal from Wastewater

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ABSTRACT

The rapid expansion of battery manufacturing, electroplating, and metal processing industries has led to increasing discharge of nickel into wastewater, posing environmental and regulatory challenges. Conventional wastewater treatment techniques often suffer from poor selectivity, high chemical consumption, and secondary waste generation, while traditional solvent extraction processes rely on toxic and volatile organic solvents. In this study, a green-solvent- based membrane- assisted solvent extraction (MASE) process is developed for the sustainable removal of nickel from wastewater. Hydrophobic deep eutectic solvents (HDES) prepared from menthol and capric acid were employed as the extraction medium and diluted with dimethyl carbonate, a green diluent, to improve viscosity and mass transfer characteristics. A Poly Vinylidene Fluoride fluoride (PVDF) membrane contactor was used to facilitate non-dispersive contact between the aqueous and organic phases, minimizing solvent loss and enhancing operational stability. The effects of key operating parameters such as pH, flowrate, and solvent composition on metal removal efficiency were systematically investigated. The proposed MASE system demonstrated effective removal of nickel under mild operating conditions, along with good solvent regeneration ability and membrane stability. The developed process offers an environmentally benign and scalable approach for the selective removal and potential recovery of nickel from industrial wastewater, contributing to sustainable wastewater treatment and resource recovery.

Keywords: Membrane-Assisted Solvent Extraction; Green Solvents; Hydrophobic Deep Eutectic Solvents; Nickel Removal; Wastewater Treatment.

Design and Development of an Adjustable Chassis Multi-Purpose Agricultural Vehicle Powered by a Hydrogen Fuel Cell Integrated Fertilizer Spraying System

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ABSTRACT

Agriculture is undergoing a transition toward sustainable and energy-efficient technologies due to increasing environmental concerns and rising operational costs. This project presents the design and development of an adjustable chassis-based multi-purpose agricultural vehicle integrated with a fertilizer spraying system powered by a hydrogen fuel cell. The proposed system incorporates an adjustable chassis mechanism that enables the vehicle to adapt to different crop row spacings, making it suitable for diverse agricultural applications. A hydrogen fuel cell is employed as the primary energy source to generate electricity, which is used to recharge an onboard battery. This battery powers a DC motor-driven pump responsible for spraying liquid fertilizers uniformly across crops. The integration of a hydrogen fuel cell provides a clean and renewable energy solution, reducing dependence on fossil fuels and minimizing emissions. The spraying system is designed to ensure controlled flow rate and efficient distribution, thereby reducing fertilizer wastage and labor requirements. The combined system enhances operational efficiency by integrating mobility, adaptability, and spraying functions into a single unit. The developed model is lightweight, cost-effective, and easy to operate, making it particularly beneficial for small and medium-scale farmers. The use of hydrogen energy further promotes sustainable agricultural practices. Overall, the proposed system demonstrates improved adaptability, energy efficiency, and environmental friendliness compared to conventional agricultural methods.

Keywords: Adjustable Chassis; Hydrogen Fuel Cell; Fertilizer Spraying System; Agricultural Vehicle; Sustainable Agriculture.

Green Synthesis of Superconductors (BSCCO) Using A Natural Solvent (NADES)

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ABSTRACT

Ionic liquids and deep eutectic solvents (DES) have been widely explored across various chemical applications due to their tunable physicochemical properties, low volatility, and potential for green processing. However, their use as chelating agents in the synthesis of phase-pure metal oxides remains limited, primarily because of the high cost of conventional ionic liquids and their inability to effectively solubilize certain water-insoluble metal salts such as bismuth nitrate. In this study, a cost- effective natural deep eutectic solvent (NADES) composed of betaine and D-(+)-glucose is introduced as an alternative reaction medium for the synthesis of a quinternary superconducting metal oxide, BSCCO (Bi-2212). The NADES system demonstrates strong solvating capability, enabling the homogeneous incorporation of otherwise insoluble precursors and promoting improved reaction uniformity. Following calcination, the method yielded over 90% of the desired superconducting phase, indicating high process efficiency and minimal material loss. Additionally, the temporal stability of the NADES was evaluated to understand its influence on precursor integrity and final product quality, revealing consistent performance over time. The findings highlight the potential of NADES as an economical, environmentally responsible, and scalable platform for advanced ceramic synthesis, offering a promising pathway toward sustainable production of high-performance superconducting materials for technological and industrial applications.

Keywords: Natural Deep Eutectic Solvent (NADES); Green Synthesis; BSCCO (Bi-2212); High- Temperature Superconductors; Ionic Liquids

Hydraulic Transient and Structural Analysis of a Condenser Water System Using Caeser II and Aft Impulse Software

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ABSTRACT

This study presents a comprehensive evaluation of a condenser cooling water piping system through integrated structural and transient analysis using CAESAR II and AFT Impulse. The piping network is modeled in CAESAR II to assess stresses, displacements, and support reactions under sustained, thermal expansion, and operating load conditions. Critical regions such as elbows, tees, and branch connections are examined to identify stress concentrations and verify compliance with allowable limits. The analysis indicates that the system operates within safe stress limits, with a maximum stress of approximately 40% of the permissible value, ensuring structural reliability. In addition to steady- state analysis, transient surge behavior is evaluated using AFT Impulse to study the effects of pressure fluctuations caused by operational disturbances such as valve closure and pump trip conditions. The surge analysis highlights pressure wave propagation, peak pressure variations, and the potential for adverse phenomena such as water hammer and column separation. The study emphasizes the importance of considering both mechanical and hydraulic aspects in piping system design. Overall, the integration of stress and surge analysis provides a more realistic assessment of system performance, contributing to improved safety, reliability, and design optimization of industrial piping networks.

Keywords: Pipe Stress Analysis; Surge Analysis; Water Hammer; Transient Flow; Thermal Expansion; Pressure Surge.

Microalgae as Biostimulants and Biocontrol Agents for Sustainable Crop Production

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ABSTRACT

Microalgae was found to be a viable biostimulant due to its fast growth, ability to be cultivated easily, stress tolerance against factors like drought and salinity, and efficiency in nutrient usage. Chemical fertilizers have been the cause of multiple problems such as soil deterioration and decrease in microbial activity of the soil. Increased accumulation of chemical residue can cause risks to animal and plant health. Hence there is a need to switch to bio-based fertilizers. Microalgae can fix atmospheric nitrogen, solubilize phosphorus using exopolysaccharides and organic acids. This greatly increases the soil fertility and aids in plant growth. The metabolites present in microalgae that are involved in biostimulation of plants are phytohormones (auxins and cytokinins), amino acids, antioxidants and antimicrobial compounds. Furthermore, microalgae also contains allelochemicals that reduce the dependency on toxic pesticides. However, high production costs, expensive cultivation, inconsistent results and short shelf life limits the use of microalgae as a biostimulant at a larger scale. Regardless of the limitations, microalgae can be considered as a suitable replacement for chemical fertilizers and pesticides in the future of agriculture.

Keywords: Nano Sized Graphene Oxide Nanoparticles; Adsorbents; Methylene Blue Dye; Visible Light; Photo Catalytic Degradation.

Comparative Review of Gas Sensors for Detection of Food Spoilage in Smart Packaging Systems

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ABSTRACT

Food spoilage is a major issue in the food industry, leading to both economic losses and potential health risks. Traditional methods used to assess food quality, such as microbiological and chemical analyses, are often time- consuming, require sample destruction, and are not suitable for real-time monitoring. To overcome these limitations, smart packaging systems integrated with gas sensing technologies have gained attention as an effective solution for continuous and non-invasive monitoring of food freshness. This review focuses on comparing different types of gas sensors used in smart packaging for detecting spoilage-related gases such as ammonia (NH_3), carbon dioxide (CO_2), hydrogen sulfide (H_2S), and volatile organic compounds (VOCs). Various gas sensors, including metal oxide semiconductor (MOS) sensors, electrochemical sensors, optical sensors, and colorimetric indicators, are discussed and evaluated based on their performance. Parameters such as sensitivity, selectivity, response time, cost, and stability are considered for comparison. MOS sensors are commonly used due to their high sensitivity and low cost, but they often face issues like poor selectivity and high energy requirements. Electrochemical sensors offer better accuracy and lower power consumption, while optical and colorimetric sensors provide simple and user-friendly visual detection, although they may have limitations in precision and long-term reliability. Recent developments in nanomaterials and hybrid sensor technologies have improved sensor efficiency and enabled better integration into modern packaging systems. However, challenges such as environmental interference, durability, cost, and large-scale implementation still remain. This review highlights key advancements, compares existing technologies, and identifies gaps, emphasizing the need for more reliable, cost-effective, and sustainable gas sensing solutions for future smart packaging applications.

Keywords: Smart Packaging; Gas Sensors; Food Spoilage Detection; Volatile Organic Compounds (VOCs); Real-Time Monitoring.

Green Synthesis of Silver Nanoparticle for Adsorption of Heavy Metal Ions from Dairy Industrial Waste Water

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ABSTRACT

Nanotechnology plays an important role in environmental remediation, particularly in wastewater treatment. Nanotechnology has a wide range of applications. This makes it a very important technology of the future. Its application in water and wastewater purification is of great interest not only in developing countries but also in the developed countries. Rapid industrialization has resulted in the discharge of large amounts of toxic pollutants into water bodies. Industrial effluents, especially dairy wastewater, contain toxic heavy metal ions that pose serious environmental and health risks. This study focuses on the green synthesis of silver nanoparticles using plant extract and their application in removing heavy metal ions from dairy industrial wastewater. The synthesized nanoparticles were characterized using analytical techniques Batch adsorption experiments were conducted to evaluate the removal efficiency of heavy metals such as lead, cadmium, and chromium. The results indicate that silver/copper nanoparticles exhibit high adsorption capacity due to their large surface area and strong interaction with metal ions. The study demonstrates that nanoparticle-based adsorbents provide an efficient, eco-friendly, and cost-effective method for wastewater treatment.

Keywords: Smart Packaging; Gas Sensors; Food Spoilage Detection; Volatile Organic Compounds (VOCs); Real-Time Monitoring

A Sustainable Approach for the Separation and Recovery of Dyes Via Bio-Polymer Based Complexation Ultrafiltration

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ABSTRACT

Aligned Sustainable Development Goal (SDG): SDG – 6

Freshwater resources are under increasing stress worldwide due to rapid population growth and expanding industrial activities. As a result, large quantities of wastewater are generated and often released into natural water bodies without adequate treatment. Among various contaminants present in wastewater, dye effluents pose a significant environmental concern because of their complex chemical structure and high toxicity. Synthetic dyes are particularly problematic, as they are persistent, resistant to biodegradation, and capable of bioaccumulation even at low concentrations. Conventional wastewater treatment techniques, including adsorption, coagulation, and precipitation, have been widely employed for dye removal; however, their efficiency is often limited. In recent years, membrane-based separation techniques, especially complexation ultrafiltration (C-UF), have emerged as promising alternatives for dye effluent treatment. This technique relies on water-soluble complexing agents to facilitate dye separation. Biopolymer- based complexing agents, such as chitosan derivatives, have attracted considerable interest due to their renewability and biodegradable nature. In this study, carboxymethyl chitosan (CMC) was employed as a complexing agent to remove cationic dye Rhodamine B. A key advantage of CMC is its ability to interact effectively with dye. The effects of operating parameters, including solution pH, CMC-to-dye ratio (w/w), and initial dye concentration, were systematically examined to evaluate their influence on dye removal efficiency. The findings demonstrate that C-UF using CMC is an effective and reliable method for removing Rhodamine B from wastewater.

Keywords: Chitosan; Complexation Ultrafiltration; Dye Effluent; Anionic Dye; Rhodamine B

Natural Juliflora Based Coatings to Protect Metals from Corrosion and Acids

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ABSTRACT

This research focuses on the synthesis and characterization of an eco-friendly, "green" anticorrosive coating to provide a sustainable alternative to toxic synthetic inhibitors. *Prosopis juliflora*, an invasive plant species, is utilized as a primary source of natural corrosion inhibitors due to the high concentration of tannins and lignin compounds in its bark. These bioactive molecules act by adsorbing onto the metal surface, forming a protective chelate complex that prevents oxidation. In this study, the bark extract was incorporated into a Polyvinyl Alcohol (PVA) polymer matrix to enhance film-forming properties and surface adhesion. The coating was synthesized by blending concentrated extract with a PVA solution, followed by controlled thermal treatment. The structural and morphological properties of the coating were analysed using FTIR, while the corrosion inhibition efficiency was evaluated through electrochemical techniques. Preliminary results indicate that the P. juliflora-PVA composite provides a significant barrier against corrosive media, demonstrating the potential of utilizing invasive floral waste for high-value industrial applications in metallurgy and surface engineering.

Keyword: Prospis Julifloral; Anticorrosive Coating; Alternative for Synthetic Chemicals; Combine with Poly Vinyl Alcohol.

Removal of Dye from Aqueous Solution using Adsorbents from Natural and Synthetic Sources

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ABSTRACT

The removal of synthetic dyes from wastewater is a critical environmental challenge due to their complex structure, high stability, and resistance to biodegradation. This study investigates the adsorption of Brilliant Blue dye from aqueous solutions using Fuller's clay as a low-cost natural adsorbent. Batch adsorption experiments were performed to evaluate the effects of operational parameters such as pH, contact time, adsorbent dosage (0.1–3 g/L), and initial dye concentration (100–1000 ppm). The adsorption process was analyzed using kinetic models, including pseudo-first-order and pseudo-second-order equations, and equilibrium data were fitted to Langmuir and Freundlich isotherm models. The results indicated that the adsorption followed pseudo-second-order kinetics, suggesting chemisorption as the dominant mechanism, while the Langmuir isotherm provided a better fit, indicating monolayer adsorption on a homogeneous surface. Maximum removal efficiency was observed at optimal pH and increased adsorbent dosage. The findings confirm that Fuller's clay is an efficient, economical, and sustainable material for dye removal in wastewater treatment applications.

Keywords: Brilliant Blue Dye; Batch Adsorption; Low-Cost; Natural Adsorbent

Sustainable Carbon Capture and Sequestration Frameworks: Agricultural Waste-Derived Cellulose Nanocrystals in Hybrid Polymer and Aerogel Systems

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ABSTRACT

It is common knowledge that carbon emissions are harmful to the atmosphere and represent a growing global challenge. Recent innovations in an effort to mitigate the scourge of anthropogenic carbon output on the environment includes the use of through Carbon Capture and Sequestration (CCS) systems to remove carbon dioxide CO_2 from flue gas. This paper explores a framework for capturing CO_2 using cellulose nanocrystal (CNC) aided polymers and aerogels derived primarily from agricultural waste. Specifically, this paper suggests utilizing common runoff materials, such as coconut husk and banana fibre, as raw sources for nanocellulose extraction. CNCs produced from these sources can be processed, blended, and doped onto high-performance polymers, such as Pebax®, or integrated into porous aerogels to increase CCS efficiency beyond that of neat materials. By leveraging the high surface area and tuneable surface chemistry of CNCs, these hybrid membranes exhibit enhanced gas permeability and selectivity. This results in sustainably manufactured filtration systems that reduce reliance on synthetic precursors. Finally, this paper explores the deployment, economic feasibility, and potential scalability challenges associated with this framework, arguing in favour of large scale deployment of the same offers a myriad of benefits including, effective carbon mitigation and the promotion of a circular bio-economy.

Keywords: Carbon Capture; Sequestration; CNC; Bioeconomy

Silicon Nanoparticles Derived from Bamboo Leaves for Methylene Blue Adsorption Using Sol Gel Method

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ABSTRACT

Silicon nanoparticles derived from bamboo leaves using the sol–gel method have gained significant attention as an eco-friendly and cost-effective adsorbent for wastewater treatment. In this experiment bamboo leaves, an abundant agricultural waste, were utilized as a sustainable silica source to synthesize silicon nanoparticles through a controlled sol–gel process. The prepared nanoparticles were characterized using techniques such as SEM, FTIR, and XRD to confirm their morphology, functional groups, and amorphous nature. The synthesized silicon nanoparticles exhibited a high surface area and porous structure, making them highly effective for adsorption applications. The adsorption performance of the nanoparticles was evaluated using methylene blue dye as a model pollutant under varying experimental conditions, including pH, contact time, and initial dye concentration. Results indicated that maximum adsorption efficiency was achieved at alkaline pH and equilibrium was reached within a short duration, demonstrating rapid adsorption kinetics. The adsorption mechanism followed pseudo-second-order kinetics and was best described by the Langmuir isotherm model, indicating monolayer adsorption on a homogeneous surface. The experiment highlights the potential of bamboo-derived silicon nanoparticles as a low-cost, sustainable, and efficient adsorbent for the removal of methylene blue from aqueous solutions, contributing to advanced wastewater treatment technologies.

Keywords: Silicon Nanoparticles (SiNPs); Bamboo Leaves; Sol–gel Method; Green Synthesis; Silica Extraction; Agricultural Waste Valorization; Nanomaterials; Adsorption; Methylene Blue Removal; Wastewater Treatment.

Energy-Efficient Model Predictive Control for Minimizing Specific Energy Consumption in Spray Drying of Morinda Citrifolia Extract

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ABSTRACT

The encapsulative spray drying of heat-sensitive herbal extracts, such as *Morinda citrifolia L.* (Noni), in carriers like maltodextrin is a complex, energy-intensive process that demands high thermal energy input, consequently creating a significant risk of thermal degradation for sensitive bioactive compounds. Conventional controllers often overlook critical physicochemical constraints - specifically the Glass Transition Temperature (TG) and stickiness factor, leading operators to consider over-drying of the product to prevent the issue of wall fouling. Consequently, focus has shifted towards intelligent control strategies capable of managing these multivariable systems with strict thermodynamic constraints. Model Predictive Control (MPC) offers a solution by utilizing a data-driven model to optimize input parameters, thereby minimizing fouling risks and preventing degradation of Bioactive compounds. By enabling operation at reduced temperatures and higher outlethumidities closer to the thermodynamic limit, MPC facilitates a reduction in Specific Energy Consumption (SEC) and optimized pharmaceutical drying operations. In this study, the control model was derived from a Step test in MATLAB, based on pilot-scale experimental data, and integrated using standard MPC toolkits. The predictive controller demonstrated robust performance, even under noisy operating conditions, and achieved considerable reduction in SEC and product yield variance compared to conventional controllers.

Keywords: Morinda Citrifolia Extract; Model Predictive Control; Specific Energy Consumption; Data- Driven Decision Making; Yield Optimization.

A Study of Vaccum Operation of Rerun Column in the Prefractionating Section Mitigate Fouling

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ABSTRACT

Fouling in vacuum distillation and rerun columns is a major operational challenge in petroleum refining, leading to reduced heat transfer efficiency, increased pressure drop, unplanned shutdowns, and loss of product quality. In the prefractionating section, the rerun column plays a crucial role in recovering valuable lighter fractions from heavier streams under controlled vacuum conditions. This study focuses on the vacuum operation of the rerun column in the prefractionating section to mitigate fouling and improve separation efficiency. A detailed process analysis was carried out to evaluate the influence of operating parameters such as column pressure, temperature profile, reflux ratio, and bottom temperature on fouling tendency and product recovery. The effect of vacuum pressure on vapor-liquid equilibrium and residence time within the column was studied using simulation-based analysis in Aspen HYSYS/Aspen Plus. Lower operating pressure was found to reduce the boiling temperature of heavy hydrocarbons, thereby minimizing thermal degradation and coke precursor formation, which are the primary causes of fouling. The optimized vacuum conditions resulted in improved separation efficiency, reduced heavy component deposition, and enhanced operational stability of the rerun column. The study provides practical insights for refinery process optimization and offers an effective strategy to reduce maintenance frequency and improve overall unit performance.

Keywords: Vacuum Distillation; Rerun Column; Prefractionating Section; Fouling Mitigation; Aspen Simulation; Process Optimization.

Hot NanoFluid Using Enhanced Oil Recovery: Viscosity Reduction and Mobility Control

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ABSTRACT

Enhanced oil recovery (EOR) of heavy crude oil is often limited by high viscosity and poor mobility control. In this study, activated carbon nanoparticles derived from Casuarina wood were used to develop a hot nanofluid system for improving oil recovery efficiency. The synthesized nanoparticles exhibited high surface area (850–1200 m^2/g) and good stability (zeta potential: −35 to −50 mV). Experimental results showed a significant reduction in crude oil viscosity from 3200 cP to 350 cP at 120°C and 0.5 wt.% nanoparticle concentration. Interfacial tension decreased from 28 mN/m to 4 mN/m, enhancing capillary number and oil mobilization. Core flooding experiments demonstrated an increase in recovery factor from 42% (water flooding) to 76% using hot nanofluids. The improved performance is attributed to combined effects of viscosity reduction, wettability alteration, and mobility control. The study highlights the potential of biomass-derived nanofluids for efficient and sustainable EOR applications.

Keywords: Enhanced Oil Recovery; Nanofluids; Activated Carbon; Viscosity Reduction; Mobility Control.