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BOOK OF ABSTRACTS



7th International Conference on Sustainability in Process Industry (SPI-2026)



FEBRUARY
09-10
2026

Organized by:

Department of Chemical Engineering,
University of Engineering & Technology, Peshawar



BOOK OF ABSTRACTS

7th International Conference on Sustainability in Process Industry

(SPI-2026)



February 9-10, 202

in collaboration with



Organized by



**Department of Chemical Engineering
University of Engineering & Technology (UET)
Peshawar**

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BOOK OF ABSTRACTS

*7th International Conference on Sustainability in process industry (SPI-2026)
February 9-10, 2026*

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PREFACE

There has never been a time where the need for sustainability has been felt as profoundly as is evident from the global events of today. The global geopolitical situation, emergence of new world players, decline in influence of current super powers, struggle for controlling the worlds resources, emergence of new economic blocks, utilization of resources to their optimum in today's changing world all dictate that our survival lies in a renewed strategy to use our limited resources especially in a sustainable way. Hence the new industrial, social, cultural, and environmental scenarios have to be analyzed and new strategies are to be devised so as to make our living sustainable. This need has been felt and thought after since last two decades and recognized in our department which plays a vital role in indigenous and global research to contribute towards the sustainable development of Pakistan in the areas of vital importance such as process industries, use of natural resources, recycling, and reuse.

This international event of “Sustainability in Process Industry (SPI-2026), (February 9-10, 2026) hosted by the Department of Chemical Engineering, University of Engineering and Technology Peshawar has been an event attracting the cutting-edge research from the renowned researchers of both national and international repute since its first inception in 2012. The conference has been an on-campus participating event, while in 2020 due to COVID-19, the conference was held online for the first time.

The 1st conference on “Sustainability in Process Industry (SPI-2012), was held at UET, Peshawar on March 28, 2012, 2nd on “Sustainability in Process Industry (SPI-2014)”, on May 22, 2014, 3rd conference in this series, “Sustainability in Process Industry (SPI 2016)” was held on October 19-20, 2016 and 4th conference on “Sustainability in Process Industry (SPI 2018)” was organized on October 24-25, 2018 with the support of Higher Education Commission (HEC), Frontier Works Organization (FWO), and in collaboration with PASTIC. The 5th conference on “Sustainability in Process Industry (SPI 2020)”, was held online on our Departments Silver Jubilee (1995-2020), utilizing indigenous resources. Similarly, the 6th conference on “Sustainability in Process Industry (SPI 2022)”, was held on October 19-20, 2022 at GIKI Swabi with the collaboration of the Department of Chemical Engineering, GIKI Swabi.

This year, the SPI-2026 has been arranged on February 9-10, 2026 by the Department of Chemical Engineering at the University of Engineering and Technology Peshawar.

Prof. Dr. Mohammad Younas
Conference Chair (UET)

ACKNOWLEDGEMENT

It is our great pleasure to welcome you to the 7th international conference of the series, “Sustainability in Process Industry (SPI-2026)”. Putting together, SPI-2026 was a team effort including faculty members, students and conference participants. We greatly appreciate all the authors/researchers for providing the content of the program in the form of oral presentations and the other participants. We are also grateful to the keynote speakers from academia and various industries. These valuable talks can and will guide us to a better understanding of “Sustainability in Process Industry”. We also thank the host organization, UET, Peshawar, and our generous sponsors PASTIC, Technology Links and HEC without their support it would have not been possible to hold this conference. We are grateful to all the organizers, who worked hard in order to make the conference successful.

ABOUT PASTIC

The Pakistan Scientific & Technological Information Centre (PASTIC) is a constituent organization of the Pakistan Science Foundation (PSF) operating under the Ministry of Science and Technology (MoST), Government of Pakistan. PASTIC is a premier national institution specialized in the collection, organization, management, and dissemination of Scientific and Technological Information (STI) to support research, development, and industrial innovation across the country.



The PASTIC National Centre is located at the Quaid-e-Azam University Campus, Islamabad, with a nationwide network of six Sub-Centres in Karachi, Lahore, Peshawar, Quetta, Faisalabad, and Muzaffarabad, ensuring broad regional outreach.

Since its inception, PASTIC has played a pioneering role in supporting Pakistan's research community, particularly during the early stages of national S&T infrastructure development. Its services historically included the supply of scientific and technical literature, abstracts and indexes, bibliographies, translations, patent information, science reference library services, technological information transfer, computer-based information dissemination, and reprographic and publication services.

For further information, please visit www.pastic.gov.pk

Objectives of PASTIC

- Development and management of National Scientific & Technological Information (STI) resources and databases
- Dissemination of STI through modern and contemporary information tools
- Collaboration and cooperation with institutional libraries and repositories for resource sharing
- Promotion of R&D-based industrial development
- Printing and publication of S&T and R&D literature
- Capacity and skill development of researchers, information professionals, innovators, and entrepreneurs
- Establishment of national and international collaborations with information networks

S&T Publications

- *Technology Roundup*: A bi-monthly bulletin featuring repackaged global trade and technology information
- *Conference Abstract Books*: Publication and printing support for abstract books of national S&T conferences (on request)

Online Databases and Information Systems

- Pakistan Science Abstracts (PSA): Abstracts of research published in Pakistani S&T journals and conference proceedings
- National Digital Archive (NDA): Full-text digital repository of Pakistani scholarly journals
- PakCat – Union OPAC of scientific and technological libraries in Pakistan
- Digital Repository of Indigenous S&T Literature
- Directory of Scientific Periodicals of Pakistan
- Database of R&D Projects Executed in Pakistan
- Database of Books Published by Pakistani Authors
- National Scientists Directory (NSD)
- Industry-related databases (industries, industrial challenges, and related information)

Promotion of Commercializable Technologies

PASTIC organizes STEM and IT Expos to promote indigenous R&D outputs, SMEs, technologies, products, and services, while empowering youth and the general public with modern information access and dissemination practices.

National Science Reference Library

A state-of-the-art Library facilitating the researcher through following services: Reference & Referral Services; Reader Service; Internet Service, Journal Listings; Photocopying & Scanning Services and Digital Library services.

Skill Development and Capacity Building

- Young researchers (data analysis, reference management, research tools)
- Women entrepreneurs (e-marketing and e-business skills)
- Library professionals (library automation and digitization)
- Journal publishers and editors (e-journal management and publishing)
- Researchers and innovators (intellectual property rights and media & information literacy)

CONFERENCE PROGRAM

Venue: Video Conference Hall
University of Engineering & Technology, Peshawar

1st Day, February 9, 2026

- 11:00-01:00 **Registration:** Inauguration ceremony
02:00-02:05 Recitation of the Holy Quran
02:00-02:15 Welcome address by **Prof. Dr. M. Younas** (Conference Chairman)
02:15-02:30 Opening Remarks by **Prof. Dr. Rizwan Gul** (Senior Dean, Faculty of Mechanical, Chemical and Industrial Engineering)
02:30-02:50 Address by **Dr. Muhammad Akram Shaikh** (DG, PASTIC)
02:50-03:20 Address by **Prof. Dr. Sadiq Khattak** (VC, UET, Peshawar)
03:20-03:40 **Plenary Talk 1** by **Haq Minhas** (CEO–MCPS, DMD PECGR Petroleum Engineer)
03:40-04:00 **Tea Break**

Technical Session-I (Video Conference Hall)

MATERIALS ENGINEERING-1

Session Chair: Dr. Khurram Shehzad Baig

Session Co-Chair: Prof. Dr. Saeed Gul

- 04:10-04:30 KN-01 Sustainable Manufacturing in Pakistan by **Dr. Khurram Shehzad Baig** (PAF-IAST, Haripur)
04:30-04:45 ME-01 Experimental evaluation of tensile strength in thin bitumen films by **Abdul Samad** (MUET Jamshoro)
04:45-04:50 ME-02 Low-Cost Magnetic Biochar Composite: Eco-friendly Synthesis, Characterization, and Application for heavy metal removal by **Ayman Asghar, Sadia Mehmood**, Pak Austria Institute of Applied Sciences and Technology Mang, Haripur
05:00-05:15 ME-03 Low-Cost Magnetic Biochar Composite: Eco-friendly Synthesis, Characterization, and Application for heavy metal removal by **Mamoona Alam**, Shaheed Benazir Bhutto Women University
05:15-05:30 ME-04 Hydroxyapatite HA Coating for Biomedical Applications by **Sana Bukhari** (UET Peshawar)
05:30-5:45 ME-05 Synthesis of UIO-66 metal- organic framework by a microwave-assisted approach, subsequently doped with nickel and zinc nanoparticles for the efficient hydrogenation of carbon dioxide into useful hydrocarbons, achieving maximal conversion and good selectivity at low temperatures by **Muhammad Abdullah** (UET Lahore)
05:45-06:00 ME-06 An evaluation of the effectiveness and feasibility of lithium-ion batteries to electric vehicles by **Abdullah Niaz** (PAF-IAST, Haripur)

Technical Session-II (Electrical Hall)
MATERIAL ENGINEERING-2

Session Chair: Dr. Sajjad Hussain

Session Co-Chair: Dr. Naseer Ahmed Khan

- 04:10-04:30 KN-02 Electrochemical remediation technologies of Per- and Polyfluoroalkyl substances (PFAS) *by Dr. Sajjad Hussain* (GIKI Swabi, UFAM Brazil)
- 04:30-04:45 ME-07 An evaluation of the effectiveness and feasibility of bioscrubbers for the removal of hydrogen sulfide and ammonia in wastewater treatment industries *by Muqaddas Noor* (PAF-IAST, Haripur)
- 04:45-05:00 ME-08 Enhanced removal of pharmaceutical waste using magnetic layered double hydroxide based bio composite by adsorption and photo degradation *by Salman Khan* (UET, Peshawar)
- 05:00-05:15 ME-09 Effect of Layered double hydroxide on the production and properties of Cement *by Mian Iqbal Ahmad* (UET, Peshawar)
- 05:15-05:30 ME-10 Addition of inorganic Anti-block in UF/MF resin for humidity resistance to avoid blocking of impregnated paper in stack *by Yasir Khan* (UET, Peshawar)
- 05:30-05:45 WC-11 Experimental investigation of bubble dynamics in vertical water channels/vessels *by Nadeem, Taha* (UET, Peshawar)

Technical Session-II (Smart Room Industrial Engineering)

MINERALS, MATERIAL AND RENEWABLE ENGINEERING

Session Chair: Dr. Imran Khan Rind

Session Co-Chair: Dr. Saira Bano

- 04:10-04:30 KN-03 Comparative study of metal adsorption onto activated and magnetic based hydrochar for their possible applications in water treatment *by Dr. Imran Khan Rind* (University of Sind, Jamshoro)
- 04:30-04:45 Min-12A An experimental investigation of copper recovery from tailings *by Shahrukh Hassan* (UET, Peshawar)
- 04:45-05:00 ME-13 Tuning the Percolation Threshold of LATP Fillers in PVDF Matrices to Engineer Fast Li-Ion Conduction Pathways in Composite Solid-State Electrolytes *by Talha Hassan* (NED, Karachi)
- 05:00-05:15 RE-14 An Evaluation of the Effectiveness and Feasibility of Specific Clean Technologies in Renewable Energy: Biodiesel, Bioethanol, and Biogas Production in Pakistan *by Muhammad Shahzaib* (PAF-IAST, Haripur)
- 05:15-05:30 RE-15 Waste oil to high performance bio-aviation fuel *by Abeera* (PAF-IAST, Haripur)
- 05:30-05:45 RE-16 Hybrid Co-Combustion of Coal Dust with Biomass *by Danial Ahmad* (UET, Peshawar)
- 05:45-06:00 Min-12B Studying iron ore recovery under different operating conditions *by Zakria* (UET Peshawar)

2nd Day, February 10, 2026
Technical Session 4 (Video Conference Hall)
Modelling and Simulations-ASPEN & CFD

Session Chair: Prof. Dr. Atta Ullah
Session Co-Chair: Dr. Naseer Ahmed Khan

- 09:00-09:20 KN-04 Using machine learning to bridge the gap between experiments and modeling of energy systems *by Prof. Dr. Atta Ullah* (PIEAS, Islamabad)
- 09:25-09:40 MOD-17 Flare gas Recovery by retrofitting of Flare gas system in a gas processing plant *by Muhammad Abbas* (UET, Peshawar)
- 09:40-09:55 MOD-18 A Multi-Physics CFD Framework for Modeling Adsorption and Fouling Dynamics in Multi-Channel Mixed-Matrix Membranes for Micropollutant Removal from Wastewater *by Muhamad Aftab* (PAF-IAST, Haripur)
- 09:55-10:10 MOD-19 Design and Aerodynamic Performance Optimization of Blended Winglets Using RANS-Based CFD Simulations *by Muhammad Ahmed Bin Afzal* (UET, Taxila)
- 10:10-10:25 MOD-20 A computational study of segregation in a multicomponent solid-liquid fluidized bed separator *by Murad Khan* (UET, Peshawar)
- 10:25-10:40 SE-21 Integrated Mechanical-Safety Framework for High-Pressure Process Equipment *by Ahsen Aziz* (UET, Peshawar)

Technical Session 5 (Electrical Hall)
Modelling - Artificial Intelligence - 2

Session Chair: Dr. Amir Muhammad
Session Co-Chair: Dr. Imran Khan Swati

- 09:00-09:20 KN-05 Modelling and Simulations *by Dr. Amir Muhammad* (PAF-IAST, Haripur)
- 09:25-09:40 M-AI-22 Particle Resolved Simulation Study of Bidispersed Particulate Flows *by Muhammad Faraz Khan* (PIEAS, Islamabad)
- 09:40-09:55 M-AI-23 Machine-Learning Models for Optimizing Self-Healing Bio-Concrete Performance *by Muhammad Shahzad* (UET, Peshawar)
- 09:55-10:10 M-AI-24 Designing A Model Training Variant of an Artificial Intelligence System by Data Processing for Drilling Engineering Failures *by Muhammad Zaryab* (MUET, Jamshoro)
- 10:10-10:25 M-AI-25 Study of Post-Myocardial Infarction Model by Incorporating the Role of Neutrophils *by Rayyan Begum* (UET, Peshawar)
- 10:25-10:40 M-ASP-26 Assessment of Reactor Modules and Kinetic Mechanisms in Aspen Plus Simulation of Chemical Looping Combustion of Methane for the Design of a 10 kW Prototype System *by Tabasat Ahmad* (PIEAS, Islamabad)
- 10:40-10:55 M-AI-27 Experimental Evaluation and Predictive Modelling of Biopolymer-Based Drilling Fluids Under Simulated HPHT Conditions *by Zohaib Ahmed* (MUET, Jamshoro)

Technical Session 6
(Smart Room Industrial Engineering)
Online Session

Session Chair: Dr. Iftikhar Salarzai

Session Co-Chair: Dr. Mansoorul Hassan

- 09:00-09:20 KN-06 AI in Chemical Engineering *by* **Dr. Iftikhar Salarzai** (NUST, Islamabad)
- 09:25-09:40 O-P-01 Process Design Engineering *by* **Fazle Nadeem** (Qatar – Petroleum Engineering)
- 09:40-09:55 O-E-02 In-Situ Growth of CALF-20 MOF on Multi-Walled Carbon Nanotubes for Enhanced CO₂ Uptake *by* **Asmat Ullah** (UMPSA, Malaysia)
- 09:55-10:10 O-S-03 Sustainable Energy Technologies *by* **Shehbaz** (USA)
- 10:10-10:25 O-S-04 AI for sustainable process techniques *by* **Dr. Waheed Zaib** (Austria)

Technical Session 7 (Video Conference Hall)
Environment and Wastewater Treatment

Session Chair: Prof. Dr. Farid Ullah Khan

Session Co-Chair: Dr. Jamil Ahmad

- 10:45-11:05 KN-07 Vibration and Acoustics Energy *by* **Prof. Dr. FaridUllah Khan**
- 11:10-11:25 Env-28 Treatment and resource recovery from industrial paper-mill wastewater using coagulation–flocculation coupled with dissolved air flotation (DAF) *by* **Areej Khan** (PAF-IAST, Haripur)
- 11:25-11:40 Env-29 Integrating Coagulation-Flocculation and Fluidized Ceramic Membrane Filtration for effective treatment of real Industrial wastewater *by* **Asma Iqbal** (PAF-IAST, Haripur)
- 11:40-11:55 Env-30 Sustainable Produced Water Treatment in Oilfields of Pakistan Using a Low-Cost Multistage System *by* **Hassan Afzal** (MUET, Jamshoro)
- 11:55-12:10 Env-31 Domestic wastewater treatment and reuse using a decentralized system *by* **Haris** (PAF-IAST, Haripur)
- 12:10-12:25 Env-32 Treated Mine Water DO optimization to prevent industrial boiler Corrosion *by* **Muhammad Amir** (MUET, Jamshoro)
- 12:25-12:40 Env-33 Wastewater treatment in textile industry *by* **Zala Aman** (UET, Peshawar)
- 12:40-12:55 Env-34 Pyrolysis of Mixed Textile Waste for Producing Biofuel *by* **Laiba Sajjad** (UET, Peshawar)

Technical Session 8 (Electrical Hall)
Environment and Wastewater Treatment - 2

Session Chair: Engr. Irfan Khan
Session Co-Chair: Dr. Muhammad Daud

- | | | |
|-------------|---------|--|
| 11:00-11:20 | KN-08 | Sustainable energy practices in pharmaceutical Industries <i>by</i> Engr. Irfan Khan |
| 11:25-11:40 | Env-33 | Utilization of natural and synthetic coagulants/flocculants for paper fiber recovery and treatment of sundry wastewater from the paper recycling industry <i>by</i> Hajira Bibi (PAF-IAST, Haripur) |
| 11:40-11:55 | Env-34 | An evaluation of the effectiveness and feasibility of a specific clean in a specific context to mitigate both air pollution and greenhouse gas emissions <i>by</i> Muhammad Aftab (PAF-IAST, Haripur) |
| 11:55-12:10 | Env-35 | To Design, Fabrication, and Performance Analysis of an HHO Gas Generation System using Sea Water and Potassium Hydroxide Electrolytes <i>by</i> Ibrar Ali (MUET, Jamshoro) |
| 12:10-12:25 | Env-36 | Study and Analysis of Wastewater from Marble Industry in KPK <i>by</i> Kaleem Ullah (UET, Peshawar) |
| 12:25-12:40 | Env-37 | Detailed case study on the impact of specific air pollutants Nox and SOx on human health in a particular region and how climate change exacerbates these effects <i>by</i> Ayman Asghar (PAF-IAST, Haripur) |
| 12:25-12:40 | Env-37A | Preparation and analysis of a solid hybrid fuel comprising coal dust and kikar waste <i>by</i> Hajra Bibi (UET, Peshawar) |

Technical Session 9 (Smart Room Industrial Engineering)
Climate Change and Sustainability

Session Chair: Dr. Irfan Ahmad Khan
Session Co-Chair: Dr. Imran Ahmad

- | | | |
|-------------|--------|---|
| 10:45-11:05 | KN-09 | A system dynamics view of climate, water and urban growth in Pakistan <i>by</i> Dr. Irfan Ahmad Khan (UET Peshawar) |
| 11:10-11:25 | CCS-38 | Climate-Driven PM2.5 escalation and health burden in Karachi, Pakistan: a public health crisis <i>by</i> Kinza Suleman (PAF-IAST, Haripur) |
| 11:25-11:40 | CCS-39 | An evaluation of the effectiveness and feasibility of a specific clean technology in a specific context to the promotion of public and non-motorized transport <i>by</i> Zoya Khan (PAF-IAST, Haripur) |
| 11:40-11:55 | CCS-40 | Evaluating the effectiveness of early warning systems and forecasting models for predicting cloudburst <i>by</i> Umar Hadi (UET, Peshawar) |
| 11:55-12:10 | CCS-41 | Impact of specific air pollutants and the hydrological cycle on human health in Lahore, Pakistan, and how climate change exacerbates these effects <i>by</i> Laiba Gul (PAF-IAST, Haripur) |
| 12:10-12:25 | CCS-42 | Degradation of persistent organic and fluorinated “Forever” chemicals via TiO ₂ -Based Advanced Photocatalysis in Aqueous Systems <i>by</i> Muhammad Shahzaib (PAF-IAST, |

- Haripur)
- 12:25-12:40 CCS-43 Circular economy approach to utilize agriculture & paper waste to DRR & CCA by **Fahad Javed** (UET Peshawar)
- 12:40-12:55 CCS-43 Mineralogical and Chemical Investigation of the Minerals Potential Area of Chitral for Critical Elements and Rare Earths Elements by **Usman Ghani** (UET Peshawar)

2nd Day, February 10, 2026

Video Conference Hall, UET Peshawar

Closing Ceremony

- 02:00-02:05 Recitation from the Holy Quran
- 02:05-02:15 Closing remarks by **Prof. Dr. M. Younas** (Conference Chairman)
- 02:15-02:30 Closing Remarks by **Prof. Dr. Rizwan Gul** (Senior Dean, Faculty of Mechanical, Chemical and Industrial Engineering)
- 02:30-02:40 Address by **Dr. Ghazala Ali Khan** (Additional Director, STI, PASTIC)
- 02:40-03:20 Vote of thanks by **Prof. Dr. Sadiq Khattak** (VC, UET, Peshawar)
- 03:20-03:40 Certificates / Souvenirs distribution
- 03:40-03:55 Group photos
- 03:55-04:30 **Hi-Tea**

ABSTRACTS

Keynote and Invited Talks

Using Machine Learning to Bridge the Gap between Experiments and Modeling of Energy Systems

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The typical method of design and development of process industry involves thorough experimentation at three levels: lab scale, pilot scale level and industrial level. This scale requires huge investment for process evolution. In past few decades, computational fluid dynamics (CFD) has emerged to be a relatively low-cost alternative. Being a physics-based approach, CFD is a reliable tool for scientific research. However, keeping in view the computational requirements, CFD may take a lot of computational time and resources for model development and validation. In this respect, the model development may require accurate inputs in terms of physical properties and boundary conditions. This is where machine learning may be coupled with CFD to identify parameters for global process development. Once a regression model is fitted, an optimization algorithm may be used to identify the best and worst case scenario making the operating and geometric parameters available. These parameters can then be used to perform comprehensive CFD modeling of the process in question. The results thus obtained will be helpful at all scales and assist designers to reduce the number of experiments hugely. This understanding can reduce the time of process development, new material discovery and save precious financial resources.

Keywords: CFD, Machine learning, Energy systems

Comparative study of metal adsorption onto activated and magnetic based hydrochar for their possible applications in water treatment

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The study described limitations and advantages of trace metal ions removal using activated and magnetic based composite hydrochar. The hydrochar prepared by hydrothermal carbonization of biomass under different temperatures ranges to produced activated hydrochar. Study also designed to produce magnetic based activated hydrochar. Materials characterized physiochemically according to ASTM methods and also by different techniques such as FTIR, BET, XRD, SEM and EDS. Equilibrium data for isotherm and kinetic followed by Langmuir and Pseudo-second order model for metal adsorption. Fixed-bed column adsorption experiment applied for large scale water treatment applications. The obtained results showed that activated and magnetic based hydrochar were

promising to remove metal ions at optimized conditions of bed height, flow rate and metal ions concentration. Experimental results were considered at breakthrough curves and compared with kinetic models Thomas, Yoon–Nelson and Adams–Bohart. These findings showed that material considered as promising adsorbent for removal of metal ions and their possible applications in customized point-of-use water filtration.

Keywords: Hydrochar, Fixed-bed column, adsorption, metal ions contamination, water treatment

Electrochemical Remediation Technologies of Per- and Polyfluoroalkyl substances (PFAS)

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Per- and polyfluoroalkyl substances (PFAS) constitute a class of highly persistent organic pollutants that present serious environmental and public health challenges due to their extensive global use, extreme chemical stability, and resistance to conventional treatment methods. Electrochemical oxidation (EO) has emerged as a powerful and versatile advanced remediation technology capable of degrading PFAS in contaminated water systems. This chapter delivers a comprehensive examination of the fundamental principles, degradation mechanisms, and practical applications of EO for PFAS treatment. It highlights the influence of electrode materials, operational conditions, and reactive species on PFAS breakdown, emphasizing the capability of EO to achieve substantial defluorination and mineralization. Recent innovations in electrode engineering, reactor configurations, and integrated or hybrid processes are also reviewed, along with key challenges related to energy demand and large-scale implementation. By bridging scientific foundations with applied engineering perspectives, this chapter provides meaningful guidance for researchers, practitioners, and policymakers seeking sustainable and effective strategies to mitigate PFAS pollution.

Keywords: polyfluoroalkyl substances, electrochemical oxidation, Environmental contaminants, Sustainability

Breaking the Vicious Cycles: A System Dynamics View of Climate, Water & Urban Growth in Pakistan: A governance & feedback-loop perspective on why climate solutions often fail & how to fix them

Irfan Ahmad Khan

Climate change interventions in Pakistan increasingly focus on technologies, targets, and sector-specific projects. Yet despite growing investment, many well-intentioned climate solutions have produced unintended and sometimes counterproductive outcomes. This keynote argues that climate change in

Pakistan is fundamentally a systems problem, driven by reinforcing feedback loops across energy, water, agriculture, and urban development. Using a system dynamics lens, the presentation highlights how interventions such as solarized tube wells, unplanned urban housing, and mitigation projects without early stage due diligence can create vicious cycles accelerating groundwater depletion, locking in unsustainable infrastructure, and amplifying climate vulnerability. The talk emphasizes that these outcomes are not failures of technology, but failures of governance, incentives, and decision sequencing. Drawing on practical experience in climate due diligence, water governance, and policy design, the keynote outlines how systemic solutions early integration of mitigation considerations, shadow pricing of carbon, groundwater governance, and coordinated urban planning can convert vicious cycles into virtuous ones. The session aims to re-frame climate action from isolated projects toward coherent system design for long-term resilience.

Keywords: Climate change, Urban growth, Sustainability

Experimental Evaluation of Tensile Strength in Thin Bitumen Films

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Asphalt binder is a viscoelastic material that acts as a thin film between aggregates, and the ability of an asphalt mixture to resist stresses is largely attributed to binder's performance. Current asphalt binder characterization in Pakistan uses empirical methods, such as penetration and viscosity grade systems, which fail to capture the fundamental viscoelastic properties of asphalt binder. The improved Performance Grade (PG) systems which uses Dynamic Shear Rheometer (DSR) and Bending Beam Rheometer (BBR) are costly and complex for practical adoption in developing nations like Pakistan. Therefore, the recent field validated Poker Chip test for measuring the tensile strength of asphalt binders was used to characterize asphalt binders. Two binder grades, 60/70 and 80/100 and mastics at 25°C and 40°C were tested for their tensile strength in Universal Testing Machine at monotonic strain rate of 5 mm/min. Between 60/70 and 80/100 binders, former had higher values than the latter, which is consistent with so-called penetration test. For both binders, increasing temperature resulted in lower tensile strength values at both the binder and mastic levels.

Keywords: Poker Chip Test, Asphalt, Mastics, Tensile Strength

Graphene modified cellulose nanofibrous PCM microcapsules for thermal energy storage

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This study used nanocellulose generated from sugarcane bagasse to create graphene-modified cellulose nanofiber microcapsules for effective thermal energy storage. A thermally conductive composite matrix was created by first chemically extracting cellulose nanofibers from bagasse and then combining them with graphene oxide through in-situ reduction. This graphene-cellulose network was integrated into organic compounds (fatty acid) phase change material (PCM) by employing non-ionic surfactant in an improved oil-in-water emulsion technique. When compared to traditional PCM systems, the resultant microcapsules showed better thermal performance and structural stability. Well-formed spherical capsules with consistent graphene-cellulose shell structures were found through microstructural analysis. The conductive network of graphene within the nanocellulose framework significantly improved the heat transfer capabilities, according to thermal study. The ideal composition for balancing mechanical stability and thermal conductivity was determined by comparing various graphene-to-nanocellulose ratios. These microcapsules' effective combination of graphene and nanocellulose generated from biomass offers a sustainable method for developing materials for thermal energy storage. The results from (SEM, XRD, FTIR, TGA, DSC) show microcapsules maintained a high energy storage capacity while successfully preventing PCM leakage during phase transitions. The study highlights the promise of nanocellulose composites derived from agricultural residue for advanced thermal management applications, especially those aiming for great heat transfer efficiency and environmental sustainability and builds the basis for future development of bio-based heat storage materials by offering fundamental insights into the structure-property correlations of graphene-enhanced cellulose nanofiber PCM systems.

Keywords: Composites, Energy, Micro plastics

Low-Cost Magnetic Biochar Composite: Eco-friendly Synthesis, Characterization, and Application for heavy metal removal

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In this study, we present a simple and cost-effective fabrication method for synthesizing magnetic biochar composite (MBC) using low-cost pine bark waste and cobalt ferrite (CoFe₂O₄). Using batch method MCB was used for the removal study of the contaminated wastewater having lead copper, and cadmium, The morphological and chemical structure of the magnetic biochar

composite was characterized using Fourier transform Infra-Red spectroscopy (FTIR), Scanning Electron Microscopy (SEM) and X-ray diffraction microscopy. The influence of pH, initial metal ion concentration, and contact time on the adsorption efficiency of Pb (II), Cu (II) and Cd (II) onto magnetic biochar (MBC) was systematically examined. The magnetic biochar (MBC) demonstrated effective adsorption of lead, copper, and cadmium over the initial range of 6.04 to 8.04. The integration of several remarkable characteristics, including easy magnetic separation, cost-effectiveness, environmentally friendly properties, and strong sorption performance, makes magnetic biochar (MBC) a highly suitable material for industrial applications. Its potential is significant in the field of waste water treatment, where it can be utilized for the efficient removal of heavy metal contaminants, contributing to sustainable and effective wastewater management.

Keywords: Magnetic Biochar Composite, Heavy Metals, Eco-friendly Synthesis

Hydroxyapatite HA Coating for Biomedical Applications

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Hydroxyapatite (HA) coatings have emerged as one of the most popular biomedical options for orthopaedic and dental implants due to their excellent biocompatibility, osteo-conductivity, and chemical resemblance to human bone. Nonetheless, a few factors, such as brittleness and low mechanical strength, restrict the application of HA in high-stress and load-bearing applications. The proposed study aims to enhance the mechanical properties and biocompatibility of HA coatings by developing a robust spin-coating technique and investigating surface modifications. The coatings are prepared with the help of HA suspensions with different concentrations (5%, 10%, and 15% v/v) and evaluated by other techniques (SEM, XRD, and FTIR). The initial findings indicate that the spin-coated HA layers have better surface homogeneity and mechanical integrity that may lead to more robust and reliable biomedical implants. The work aims to fill significant gaps in existing HA-based coatings and assist in creating long-life bioactive surfaces for orthopaedic and dentistry.

Keywords: Hydroxyapatite Coatings, Spin Coating, Biomedical Implants

Synthesis of UIO-66 metal-organic framework by a microwave-assisted approach, subsequently doped with nickel and zinc nanoparticles for the efficient hydrogenation of carbon dioxide into useful hydrocarbons, achieving maximal conversion and good selectivity at low temperatures

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Global energy demands have increased greatly over the past two decades. Fossil fuels have traditionally supplied most of the energy demand and are the dominant source of energy supply worldwide. The major source of global energy demand is fossil fuel combustion that involves the release of many greenhouse gases in which carbon dioxide outweighs them all. Carbon dioxide has a huge impact on the environment, trapping heat and increasing the average temperature of the Earth, making it a major contributor to global warming and climate change. The continuing global warming and climate change demand special attention to the reduction of greenhouse gases including CO₂. The main challenge in this field remains to be the capturing and storage of CO₂ emissions. As the thermodynamically stable and chemically inert nature of CO₂, the catalytic hydrogenation of CO₂ to value-added products is one of the most effective and potential economical methods to reduce CO₂ emissions. Considering its high-energy content, renewable hydrogen serves as a very attractive co-reactant that allows the efficient conversion of CO₂ into useful products such as hydrocarbons. There are many catalysts that have been known to accelerate the reaction involving the conversion of CO₂. Metal-organic frameworks (MOFs) are good candidate for this purpose due to their high-exposed surface area, high crystallinity, and uniform pore-size distribution. The feature of MOFs that they can be modified by incorporating nanoparticles into their framework is particularly preferred. As these changes can improve both the selectivity and product yield in the hydrogenation method. Herein, the synthesis and doping of the UIO-66 MOF by using Microwave-Assisted solvothermal method is reported. Usually, the UIO-66 has to be fabricated by conventional reaction heating at the specific temperature for 12 h. However, if using a microwave oven, the reaction heating time will be greatly shortened to about 20 minutes. After the synthesis of UIO-66 MOF, Nickel and Zinc were chosen for post doping at 2:1 and total doping percentage of 10 wt% based on their complementarily catalytic behaviour in the hydrogenation of CO₂ to methane. Nickel (Ni) emerged as an important active metal for the Sabatier reaction, showing high hydrogenation activity and being inexpensive. The dissociative adsorption of H₂ is enabled by Ni sites for subsequent CO₂ reduction. Additionally, Ni in the UiO-66 also leads to good stability for MOF, and declines sintering while ensuring adequate dispersion, whereas Zn plays a role

of promoter. Zn^{2+} species enhance the local concentration of active intermediates on Ni sites due to their Lewis acidic sites, which are beneficial for CO_2 adsorption and activation. The electronic effect caused by the interaction between Zn and Ni modulates the surface property of catalysts to inhibit competitive RWGS reaction and promote CH_4 selectivity. The maximum CH_4 production is achieved by the combination of Ni and Zn nanoparticles in UiO-66 MOF. Analysis through EDX mapping and scanning electron microscopy indicate high dispersion of Ni and Zn nanoparticles in UiO-66 (Ni, Zn@UiO-66). The peaks detected from FTIR imply the structural persistence following doping. The clear and sharp peaks observed in the XRD graph are characteristic of high degree of crystallinity, while TGA demonstrates that UiO-66 doped sample has very good structural and thermal stability. Additionally, the BET tests confirm a large surface area which is beneficial for adsorption and conversion. In this work, Ni-Zn/UiO-66 MOF catalyst with 10% doping and a Ni:Zn ratio of 2:1 was synthesized and studied for the CO_2 hydrogenation to CH_4 . It showed high activity under the reaction temperature of 300 °C, 10 bar pressure and a GHSV of 5000 h^{-1} . The Ni-Zn/UiO-66 catalyst gave a methane yield of 72% with CH_4 selectivity of 90% and CO_2 conversion as high as 80%. As a result, Ni, Zn@UiO-66 represents a striking active site for CO_2 hydrogenation with excellent catalytic activity and stability due to the remarkable catalytic activity resulted from the effective dispersion of ultrasmall Ni and Zn NPs.

Keywords: Emissions, Greenhouse gases, Hydrogenation

An Evaluation of the Effectiveness and Feasibility of Lithium-Ion Batteries to Electric Vehicles

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The rapid transition towards sustainable transportation has positioned electric vehicles (EVs) as a cornerstone of reducing greenhouse gas emissions and fossil fuel dependency. This study evaluates the effectiveness and feasibility of lithium-ion batteries (LiBs) as the primary energy storage solution for EVs, focusing on key performance metrics such as energy density, cycle life, charging efficiency, and environmental impact. Through a comprehensive analysis of existing literature, experimental data from battery testing under various operational scenarios, and economic modeling, we assess LiBs' advantages, including high energy density (up to 250-300 Wh/kg) and long lifespan (over 1,000 cycles with minimal degradation), which enable practical driving ranges exceeding 300 miles per charge in modern EVs. However, challenges such as raw material scarcity, particularly lithium supply constraints, high manufacturing costs, and thermal management issues during fast charging are identified as barriers to widespread adoption. Feasibility is further examined through life-cycle assessments, revealing that while LiBs offer superior energy conversion efficiency (around 90-95%) compared to alternatives, their

environmental footprint can be mitigated via advanced recycling processes and second-life applications in stationary storage. The findings conclude that LiBs remain the most viable option for EV propulsion in the near term, with recommendations for policy interventions to enhance supply chain resilience and technological innovations like solid-state batteries to address current limitations. This evaluation underscores the need for balanced strategies to maximize LiBs' effectiveness while ensuring long-term feasibility in the global EV market.

Keywords: Sustainability, GHGs, Feasibility, Electric Vehicles, Lithium Battery

An Evaluation of the Effectiveness and Feasibility of Bioscrubbers for the Removal of Hydrogen Sulfide and Ammonia in Wastewater Treatment Industries

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Industrial scrubbers are widely used for controlling air pollutants; however, conventional scrubber systems often face limitations related to high-energy consumption, secondary waste generation, and operational costs. This study evaluates the effectiveness and feasibility of a clean technology-based industrial scrubber, focusing on its application in an industrial setting with high gaseous and particulate emissions. The evaluation assesses pollutant removal efficiency, operational performance, energy and water consumption, and compliance with environmental regulations. In addition, technical, economic, and environmental feasibility are analyzed by considering installation costs, maintenance requirements, resource efficiency, and potential reductions in emissions and waste generation. The results indicate that the selected clean technology significantly improves removal efficiency for targeted pollutants while reducing energy demand and environmental impact compared to conventional scrubbers. The feasibility analysis demonstrates that, despite higher initial capital costs, long-term operational savings and regulatory compliance benefits make the technology suitable for industrial implementation. Overall, the study highlights the potential of clean technology-based scrubbers as a sustainable and practical solution for industrial air pollution control.

Keywords: Absorption, Air Pollution, Scrubbers

Enhanced Removal of Pharmaceutical Waste using Magnetic Layered Double Hydroxide based Bio composite by Adsorption and Photo degradation

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This research aims to develop Magnetic Layered Double Hydroxide (MLDH) and Magnetic Layered Double Hydroxide-Starch (MLDH-S) for the effective removal of antibiotic (ciprofloxacin) by photo degradation and adsorption. This study analyses the bio composite's effectiveness and its potential for removal of antibiotic (ciprofloxacin). I prepared MLDH and MLDH-S by co-precipitation method. Cobalt (II) nitrate hexahydrate, Iron (III) nitrate nonahydrate and starch (corn starch) were used in a ratio of 3:1:1 to prepare the bio composite. Different factors such as pH, temperature, adsorbent dosage, and contact time were adjusted to produce optimal adsorption results. Pristine MLDH adsorption efficiency for ciprofloxacin (CIP) was 90.2% while its photo degradation efficiency was 93.8%. MLDH-S adsorption efficiency for ciprofloxacin (CIP) was 98.5% while its photo degradation efficiency was 99.2%.

Keywords: Adsorption, photo degradation, magnetic layered double hydroxide

Effect of Layered double hydroxide on the production and properties of Cement

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Cement is the fundamental material of construction; however, low strength, higher hydration, and curing time are real challenges, still need to be overcome. Hydrotalcites, also known as synthetic clays, are an excellent addition to the family of nanocomposites. In this research work, zinc aluminium layered double hydroxide (ZnAl-LDH) is used in mortar cement in the ratios of 1%, 3% and 5% for strength analysis with pristine mortar cement at times 2, 7, and 28 days. The strength of cement is increased from 47 to 50.60 MPa at the 5% LDH loading on the mortar time of 28 days.

Keywords: Compressive strength, Cement, layered double hydroxide

Addition of inorganic Anti-block in UF/MF resin for humidity resistance to avoid blocking of impregnated paper in stack

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The interest of laminated board has grown in recent decades, where board surface coated with resin impregnated paper. At impregnation line anti-block agent added to resin for preservation of blocking (sticking) of impregnated paper in stack until it is used for lamination purpose. Normally organic anti-block agent added to resin for preservation of blocking. In the current research an Inorganic anti-block solution of SiO₂ and Talc powder with different composition was used. Also used Organic anti-block solution (AT-837) of "WIZ Chemicals" (Italy) to compare results of both anti-block agent. Inorganic Anti-block agent solution of three types having composition of SiO₂ and Talc powder

(25:75) %, (50:50) % and (75:25) % was added to resin and after coating on paper place it in storage room in stack at 25°C and 65% RH, to determine its blocking by checking increase in volatile content. According to results it was determined that Inorganic anti-block agent solution of SiO₂ and Talc powder (75:25) % has shown high resistance to humidity due to small increase in volatile content noted, having no blocking of paper from day 1st to 30th day. In this research there were also focus to compare resistance towards humidity by inorganic anti-block with organic anti-block and replace it. The resistance to humidity by Inorganic anti-block agent solution of SiO₂ and Talc powder (75:25) % was noted same as by Organic anti-block solution (AT.837) of “WIZ Chemicals” (Italy).

Keywords: Surface coating, Laminated board, Impregnation, Anti-block.

Experimental Investigation of Bubble Dynamics in Vertical Water Channels/Vessels

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The research investigates the dynamics of bubbles in vertical channels is crucial for numerous multiphase flow problems, there remain few confined, well-controlled experiments studying the phenomena. We describe such an investigation in a vertical transparent water channel where air bubbles are generated along the base of the channel and their motion is recorded digitally under steady conditions. This work describes the formation of bubbles, the shapes of which change as a function of the rise velocity and flow regime, and their interactions. Increased bubble rise velocities and changes in bubble shape along the channel were observed. In addition, a lateral deformation of the bubble shape was noted. The results from the different phases of the flow demonstrated trajectory changes and bubble coalescence. Although the analysis centres on the experimental results primarily, the findings have been structured and contextualized to the existing surrounding literature and known physical reasoning. The findings enable documentation of a series of controlled experimental data pertaining to the behavior of gas bubbles in vertically confined flows and extend the understanding of the multiphase flow phenomena in vertical channel systems. The outcome of this study will assist future experimental and computational endeavors aimed at constructing improved estimations of multiphase flow.

Keywords: High-Speed Cameras (HSC's), User Defined Function (UDF), Three-dimensional (3D)

An experimental investigation of copper recovery from tailings

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The main objective of this research work is to discuss the global demand of copper that generates untamed mining yielding vast volumes of flotation tailing, which contain economically feasible volumes of copper. Not only does such tailings amount to wasting a precious material, but it is also hazardous to the environment when it is disposed of. The following paper discusses a hydrometallurgical process in order to extract residual copper in this type of tailings. The ore is first treated with a traditional beneficiation process consisting of crushing, grinding to a 63 μ m diameter and froth flotation in the presence of sodium amyl xanthate as collector and sodium silicate as gangue depressant to yield a primary copper concentrate. The remaining tailings, at which the percent remaining of Cu is $\geq 2\%$ are acid leached. In a representative experiment tailings (100 g) were shaken with 100 mL of 1 M H₂SO₄ at 60 °C after 2, 4 and 6 h to permit the production of a copper-enriched leachate. The recrystallized solution was further recrystallized to concentrate the dissolved Cu and a redox cementation step was followed by adding metallic iron to the filtered leachate. Visual evidence that cementation took place was observed by the development of gases, changing color and copper metallization of the iron base. The metallic copper deposited was confirmed by the use of energy-dispersive X-ray (EDX) spectroscopy. The results reveal a feasible second path of recovery that employs the balance of copper in the flotation tailing and thereby improves a superior utilization of the accessible resources and fewer impacts of the primary treatment of the mineral.

Keywords: Flotation process; Tailings; Acid leaching; Leachate solution; Copper ore

Tuning the Percolation Threshold of LATP Fillers in PVDF Matrices to Engineer Fast Li-Ion Conduction Pathways in Composite Solid-State Electrolytes

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Composite solid electrolytes (CSEs) comprising ferroelectric polymers and fast-ion conducting ceramics offer a promising pathway to overcome the safety and energy density limitations of conventional lithium-ion batteries. However, maximizing the ionic conductivity in these systems remains a challenge due to the high interfacial resistance and agglomeration of ceramic fillers at high loadings. In this study, we report the optimization of NASICON-type

$\text{Li}_{1.3}\text{Al}_{0.3}\text{Ti}_{1.7}(\text{PO}_4)_3$ abbreviated as LAMP incorporation within a fixed Poly (vinylidene fluoride) (PVDF) matrix to engineer a high-performance CSE. A series of composite membranes with varying LAMP concentrations (0%, 50%, 90% and 100% by weight) were fabricated via a solution-casting technique. Electrochemical Impedance Spectroscopy (EIS) reveals a percolation threshold at 90 wt.% LAMP, achieving a maximum ionic conductivity of $4.2 \times 10^{-4} \text{ S.cm}^{-1}$ at room temperature. This enhancement is attributed to the formation of continuous Li^+ conduction pathways and the effective reduction of PVDF crystallinity, as confirmed by XRD, SEM, FTIR and TGA analysis. Furthermore, the optimized CSE exhibits a wide electrochemical stability window up to 4.5 V vs. Li/Li^+ and a high lithium transference number (t_{Li^+}) of 0.52.

Keywords: Composite Solid Electrolyte, LAMP, Ionic Conductivity

An Evaluation of the Effectiveness and Feasibility of Specific Clean Technologies in Renewable Energy: Biodiesel, Bioethanol, and Biogas Production in Pakistan

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Pakistan's intersecting energy insecurity, climate vulnerability, and development imperatives demand comprehensive renewable energy transitions. This research systematically evaluates three biofuel pathways biodiesel, bioethanol, and biogas across technological effectiveness, economic viability, environmental sustainability, and implementation feasibility within Pakistan's specific context. Comparative analysis demonstrates that biogas technology emerges as the immediate priority for rural energy access expansion, offering superior cost-effectiveness (35-40% internal rate of return for household systems), exceptional climate mitigation potential (85-95% greenhouse gas reductions), and proven deployment success through 5,000+ installed systems across Pakistan. Molasses-based bioethanol represents the optimal medium-term opportunity, strategically leveraging existing industrial infrastructure to achieve 4–6 year capital cost recovery and 18-25% annual returns at industrial scale. Waste oil biodiesel provides an emerging opportunity contingent on integrated municipal waste management systems, while *Jatropha*-based biodiesel requires sustained long-term investment in agronomic research and market linkage development. Life cycle assessment findings reveal biogas systems achieve net negative emissions (-0.5 to -0.8 kg CO_2 emission per kilowatt-hour) through avoided methane emissions from manure decomposition, substantially exceeding climate mitigation performance of fossil fuel alternatives. Water footprint analysis demonstrates biogas and waste oil biodiesel maintain sustainability thresholds (200-400 L/L and 100-200 L/L respectively), while irrigated bioethanol production exceeds water sustainability constraints in Pakistan's water-scarce

context. Feedstock availability assessments indicate 120,000-315,000 million liters annual biofuel production potential from livestock manure alone, equivalent to 8-10% of Pakistan's total energy consumption. Strategic policy implementation through coordinated mechanisms spanning fiscal support, blending mandates, sustainability governance, and capacity development can mobilize \$2-4 billion cumulative investment, generating 50,000-200,000 employment opportunities while advancing climate commitments and sustainable development objectives.

Keywords: Biofuels, Pakistan, renewable energy, life cycle assessment

Waste Oil to High Performance Bio-Aviation Fuel

Abeera Binte Ahmed, Afeefa Khalid, Laiba Noor, Ayesha tul Rifdha, Syeda Zahara, Zain ul Abideen

Aviation fuels are a major contributor to environmental pollution and greenhouse gas emissions, creating an urgent need for sustainable and environmentally friendly alternatives. Simultaneously, waste cooking oil generated from households, food industries, and restaurants poses a serious threat to water pollution. Converting waste cooking oil into bio aviation fuel offers a dual benefit by reducing environmental waste while providing a cleaner fuel source. In this study, waste cooking oil collected from Haripur was converted into bioaviation fuel. The oil was first pretreated to remove solid impurities and moisture to prevent interference during processing. Transesterification was carried out using methanol and sodium hydroxide to convert the oil into biodiesel. The resulting biodiesel was then further processed to obtain bioaviation fuel. The final product was characterized using Fourier Transform Infrared (FTIR) spectroscopy. Successful conversion was confirmed by the presence of a strong ester carbonyl (C=O) absorption peak around 1740 cm^{-1} , distinct C–O stretching bands in the range of 1100–1300 cm^{-1} , and the absence of a broad O–H peak near 3400 cm^{-1} , indicating minimal moisture content. Compared to conventional biodiesel, bioaviation fuel exhibits lower oxygen content, higher energy density, and improved combustion stability. Although further optimization and detailed fuel property analysis are required to meet aviation fuel standards, this study demonstrates the potential of waste cooking oil as a sustainable feedstock for bioaviation fuel production. This approach contributes to waste reduction, energy sustainability, and reduced dependence on fossil fuels, supporting the development of a greener aviation industry.

Keywords: Bioaviation fuel, Waste cooking oil, Transesterification

Hybrid Co-Combustion of Coal Dust with Biomass

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An urgent energy challenge has been eminent in the current world for quite some time partially due to our reliance on fossil fuels mainly hydrocarbons.

Besides environmental pollution, there have been other supply chain security issues in the recent past which continue to escalate and result in high prices. To overcome these challenges, each developed and developing economy is investing in indigenous sources of energy including nuclear power, hydroelectric, and renewables such as solar and bio-based fuels. The cleaner and sustainable energy sources is now an essential requirement and its mainly due to this reason that we present this work for the design and development of hybrid solid energy fuel that is partially renewable by employing the biomass as a partial constituent with coal. This study chose sub-bituminous coal as a partial feedstock with biomass, which requires less initial processing and is expected to have lower environmental impacts. As a result, this fuel combines sub-bituminous coal and biomass to create a potentially viable solution that bridges the gap between traditional fossil fuels and cleaner, renewable energy. This study examined different hybrid solid fuel mixture ratios to achieve cleaner burning, lower ash content (4-5%), and high calorific value (1800-22925 J/g). The hybrid coal mix will be used in powder form (<125 μ m) in an indigenously designed laboratory-scale centrifugal furnace. The study also presented the design of a sustainable plant for producing hybrid solid fuels with material and energy balance.

Keywords: Coal, Biomass, Renewable Energy

Studying iron ore recovery under different operating conditions

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The study focused on the improved recovery of a Iron from its ore using separation techniques such as jigging apparatus under different operating conditions. An iron ore sample from Karak region was collected and was crushed and grinded for performing the experiments. The sample was first analyzed to see the iron ore content within the sample. Experiments were carried out for three different particle size range. The results showed that in the jigging apparatus the separation of particles in the size range -1+0.50 mm was the best as compared to the size range -4+1 mm particle size. Furthermore, at finer size -0.50+0.10 mm (-500+100 micron) the performance of the jigging apparatus was very low, as the most of the particles overflow due to hydraulic conveying.

Keywords: Mineral, Ore, Gravity Separation

Flare Gas Recovery by Retrofitting of Flare Gas System in a Gas Processing Plant

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Flaring of natural gas takes place in numerous industrial activities together with natural gas well drilling, gas purification and dehydration and other activities relating to oil and gas sector. The primary purpose of gas flaring is safe disposal

of waste gases and safeguarding the facilities, employees, and environment. On the other hand, flaring gas streams produces trade-off emissions of greenhouse gases (GHGs) and pollutants such as sulfur compounds to the environment. Furthermore, they also cause economic disadvantage as valuable hydrocarbon components are wasted. To recover and reuse this valuable energy resource, retrofitting of an existing flare system in a gas purification plant that operates with two elevated flare stacks for the combustion of approximately 1.2 MMscfd waste gases has been proposed. In this regard at first, several practicable options were identified and discussed for the utilization of recovered gas through cost benefit analysis. In-house resources were used from concept stage to final execution of the modified plant system. The proposal is predicted to come out with saving of more than 800 MMBtu per day which will be added to national energy resources. Additionally, there will a substantial decrease in emission of greenhouse gases and sulfur contents.

Key words: Aspen Plus, greenhouse gases, resource recovery

A Multi-Physics CFD Framework for Modeling Adsorption and Fouling Dynamics in Multi-Channel Mixed-Matrix Membranes for Micropollutant Removal from Wastewater

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Micropollutants such as pharmaceuticals, pesticides, and endocrine disruptors pose significant environmental and health risks when released into waterways via wastewater treatment plant effluents. Multi-channel mixed-matrix membranes (MCMs) with embedded powdered activated carbon (PAC) offer a promising solution, combining particulate filtration and micropollutant adsorption in a single treatment step. MCMs have shown great potential for pollutant removal, but commercialization is limited by membrane fouling causing flux decline, higher energy demand, and frequent regeneration, along with few other challenges like polymer instability, suboptimal PAC regeneration and limited adsorption-desorption understanding. This project proposes a computational fluid dynamic (CFD) framework to simulate coupled hydrodynamics, solute transport, adsorption, and fouling dynamics in PAC-embedded MCMs. The model will integrate Navier-Stokes equations for hydrodynamics, convection-diffusion for mass transfer, Langmuir isotherms for adsorption, and novel terms to simulate foulant deposition and pore blockage. It will be validated against experimental data from the hosts on the removal of micropollutants carbamazepine (CBM), paracetamol (PAR), and diclofenac (DCF). The simulations will provide insights into the spatial and temporal evolution of fouling, its interaction with adsorption sites, and its impact on regeneration efficiency, as well as pollutant adsorption, ethanol-assisted regeneration, and thermal stability effects. The goal is to use this CFD model to predict optimized membrane geometries and operational conditions that

minimize fouling and thus enabling economical, efficient and long-term operation of MCMMMs for advanced wastewater treatment.

Keywords: Computational fluid dynamics, Multi-channel mixed-matrix membrane, Micropollutants

Design and Aerodynamic Performance Optimization of Blended Winglets Using RANS-Based CFD Simulations

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The integration of blended winglets in modern aircraft design offers substantial aerodynamic advantages by reducing induced drag and enhancing lift-to-drag ratio. This research focuses on the design, simulation, and optimization of a blended winglet for a NACA 2.5411 airfoil using Reynolds- Averaged Navier–Stokes (RANS)-based Computational Fluid Dynamics (CFD) simulations. The airfoil geometry was modeled in SolidWorks and meshed using ANSYS Fluent with a fine structured grid near the boundary layer to ensure accurate flow resolution. Steady-state simulations were conducted under subsonic flow conditions at Reynolds numbers corresponding to typical cruise speeds. The velocity and pressure contours, along with lift coefficient and lift force data, were analysed to quantify aerodynamic efficiency. The results demonstrated a significant reduction in wingtip vortices, resulting in enhanced lift generation and reduced induced drag. Velocity streamlines confirmed smoother flow distribution around the winglet junction, indicating improved aerodynamic stability. The optimized blended winglet design achieved an increase in lift coefficient by approximately 8– 12% compared to the baseline configuration without winglets. This study validates the role of RANS-based CFD in optimizing winglet geometries, providing a computationally efficient approach for sustainable aerodynamic design improvements applicable to next-generation aircraft.

Keywords: Blended winglets, Aerodynamic optimization, RANS model

A computational study of segregation in a multicomponent solid-liquid fluidized bed separator

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This research work presents a CFD investigation of segregation and dispersion phenomena occurring in solid–liquid fluidized bed separators for a multicomponent system. A Eulerian–Eulerian multiphase modeling framework is implemented in ANSYS Fluent, consisting of one liquid phase and multiple solid phases having identical particle sizes but different material densities. The governing equations are solved to precisely characterize interphase hydrodynamics and particle–fluid interactions. Model predictions are validated against available experimental and computational data reported for binary

fluidized beds, showing close agreement in axial solids concentration profiles, bed expansion behavior, and overall flow trends, thereby confirming the robustness of the modeling approach. Simulation results indicate that particles initially undergo intense mixing and radial dispersion, followed by gradual axial segregation driven primarily by density differences. Heavier particles preferentially accumulate in the lower regions of the bed, whereas lighter particles migrate upward along the bed height. Increasing the liquid superficial velocity significantly enhances particle dispersion and overall bed expansion, but simultaneously weakens segregation efficiency by promoting stronger mixing. Application of the same CFD methodology to a reflux classifier further demonstrates its ability to predict multicomponent separation behavior under practical operating conditions. Overall, the findings confirm that CFD provides a reliable and powerful tool for analyzing hydrodynamics, understanding separation mechanisms, and supporting the design and optimization of industrial-scale multicomponent solid–liquid fluidized bed.

Keywords: Fluidized Bed, Segregation, Dispersion

Integrated Mechanical-Safety Framework for High-Pressure Process Equipment

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Ensuring the reliability of high-pressure process plants requires a systematic safety management approach that bridges design, operation, and risk assessment. This study proposes an integrated framework combining Failure Mode and Effects Analysis (FMEA), Finite Element (FE) stress analysis, and real-time condition monitoring to evaluate the safety of a pilot-scale heat-exchanger network. First, a comprehensive FMEA identified critical failure modes such as tube rupture and flange leakage. Next, FE simulations quantified stress concentrations under transient thermal-hydraulic loads, validating the design against ASME VIII-1 standards. Finally, a wireless sensor array was deployed to monitor temperature, pressure, and vibration, with data fed into a predictive maintenance algorithm that flags deviations exceeding two standard deviations from baseline conditions. Over six months of operation, the proposed framework reduced unplanned downtime by 38% and lowered the overall risk rating from high to medium on the facility risk matrix. The results confirm that a mechanics-driven safety management system can significantly enhance both operational safety and productivity, providing a scalable template for industrial plants handling hazardous fluids.

Keywords: Mechanical safety; High-pressure equipment; FMEA

Particle Resolved Simulation Study of Bidispersed Particulate Flows

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Understanding and predicting particle-fluid interactions in sedimenting suspensions is essential for advancing multiphase flow technologies used in chemical, environmental, and energy systems. In this study, direct numerical simulations with Smooth Profile Method was employed to investigate the settling dynamics of bidisperse spherical, non spherical particles. The spherical system was examined at an overall solid volume fraction of $\phi_t = 0.1$, where the concentration of large particles ($\phi_l = 0.001-0.5$) was varied. The non-spherical system, composed of rod- and disk-shaped particles constructed from chained spheres, was analyzed at a fixed solid fraction of $\phi_t = 0.07$ with disk volume fraction $\phi_d = 0.00-0.07$. The simulation results reveal pronounced microstructural transitions driven by bidispersity. In spherical suspensions, the first peak of the radial distribution function (RDF) weakens while a secondary peak emerges as ϕ_l increases which indicates the clustering of small spheres around large spheres. In rod-disk suspensions, increasing disk content suppresses the first two RDF peaks and leads to the formation of a tertiary peak associated with disk clustering and rod alignment disruption. Despite these structural differences, both systems exhibit consistent macroscopic trends, the mean settling velocity rises and drag decreases with higher proportions of large spheres or disks. Temporal autocorrelations also evolve, showing monotonic strengthening in spherical suspensions, whereas in rod-disk systems they first intensify (up to $\phi_d = 0.035$) and then diminish. Overall, this combined study provides a comprehensive understanding of how size and shape-induced bidispersity governs microstructural evolution, hydrodynamic interactions, and settling dynamics.

Keywords: Sedimentation, Bidisperse particles, Direct numerical simulation

Machine-Learning Models for Optimizing Self-Healing Bio-Concrete Performance

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Concrete forms the backbone of modern infrastructure, but small cracks that develop with time can significantly diminish its durability and longevity. Bio-concrete embeds beneficial microbes such as *Bacillus subtilis* or *Sporosarcina pasteurii*, offering an innovative solution through in situ precipitating calcium carbonate into the cracks. However, effectiveness depends on many factors regarding bacterial activity, nutrient supply, crack size, and environmental conditions, thereby making the performance of bio-concrete difficult to predict. In recent times, machine learning techniques have shown great promise in

helping scientists and engineers predict the efficiency of the healing in bio-concrete and optimizing its material design. This review describes how ML models, such as neural networks, support vector machines, and ensemble learning, have been used for the prediction of crack closure, strength recovery, and long-term durability of bio-concrete. It also discusses some important challenges, such as limited experimental datasets, variability in microbial behavior, and environmental influences. At the same time, hybrid models, real-time monitoring integration, and optimization frameworks can make bio-concrete more reliable and easier to deploy on a large scale. By bringing together the latest developments, this article provides a clear prospect for anybody interested in applying machine learning to improve the performance, sustainability, and resilience of bio-concrete in various infrastructure projects.

Keywords: Bio-concrete; Self-healing concrete; Machine learning

Designing a Model Training Variant of an Artificial Intelligence System by Data Processing for Drilling Engineering Failures

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Oil and gas companies often encounter drilling failures across variable formations due to bit wear, pressure fluctuations, thermal effects. And formation instability. This study aims to design and train a machine learning model capable of forecasting critical drilling problems before they occur. By integrating drilling parameters with geological inputs, the model seeks to improve decision-making, enhance drilling efficiency, reduce non-productive time, and support safer well construction practices. A machine learning system was developed using key drilling and formation parameters such as hardness, bit wear, depth, pressure variations, thermal gradients, and recorded drilling incidents. Data preprocessing included normalization, feature extraction, outlier handling, and dimensionality reduction to identify the most influential risk features. Machine learning models, specifically Random Forest and Neural Networks, were trained and validated on separate datasets. Model performance was evaluated using RMSE, precision-recall scores, and accuracy to determine reliability for real-time drilling support. The model achieved 87% accuracy. It predicted bit life within 12 hours of actual replacement time and estimated the rate of penetration with only a 0.8 m/hr error for wells between 1,000 and 5,000 meters. Pressure anomalies were detected with 89% precision and 85% recall, providing early warnings for kicks and blowouts. Predicted blowout risks closely matched actual values at multiple depths, and safe and risky zones were identified with high accuracy. High-pressure pockets matched field records, and thermal stress predictions differed by less than 5°C. This study shows that machine learning can accurately identify drilling risks in advance, helping improve safety, save time, and reduce overall drilling costs.

Keywords: Machine Learning, Drilling Failure Prediction, Drilling Optimization

Study of Post-Myocardial Infarction Model by Incorporating the Role of Neutrophils

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Myocardial infarction (MI) is a major global health concern due to the limited regenerative capacity of the heart. Immune responses following MI critically regulate inflammation, healing, and cardiac remodeling. The post MI response involves a complex multiscale interplay of cardiomyocyte death, activation of innate and adaptive immune pathways, cytokine signaling, fibroblast proliferation, and extracellular matrix remodeling. Existing ordinary differential equation (ODE) models of post-MI left ventricular (LV) remodeling have successfully described macrophage dynamics and fibrotic collagen deposition; however, the explicit roles of additional immune components such as neutrophils, dendritic cells, and T cells remain insufficiently explored. In this study, an extended nonlinear ODE model of post-MI LV remodeling is developed that incorporates both innate and adaptive immune responses, describing the temporal evolution of cardiomyocytes, dead cardiomyocytes, interleukin 1 and interleukin 10 cytokines, monocytes, classically and alternatively activated macrophages, neutrophils, dendritic cells, fibroblasts, and collagen. Parameter values and initial conditions for the core inflammatory and fibrotic processes are adopted from established post MI models, while additional immune-related parameters are selected to maintain biological realism. Qualitative analysis identifies a biologically meaningful equilibrium state associated with poor healing and demonstrates its global stability across immunological configurations. Numerical simulations reproduce characteristic post-MI dynamics reported in the literature, including rapid cardiomyocyte loss, transient cytokine peaks, macrophage polarization, and progressive collagen accumulation, while additionally revealing neutrophil-mediated regulation of fibroblast activation and fibrosis. A fast-slow model reduction further identifies dominant mechanisms governing long-term scar formation, providing a comprehensive mathematical framework for investigating immune-driven LV remodeling after MI.

Keywords: Mathematical modeling; Ordinary differential equations; Nonlinear dynamics

Assessment of Reactor Modules and Kinetic Mechanisms in Aspen Plus Simulation of Chemical Looping Combustion of Methane for the Design of a 10 kW Prototype System

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This study presents a comprehensive modelling framework for a 10kW chemical looping combustion (CLC) system using methane as the gaseous fuel. Chemical Looping Combustion (CLC) is energy efficient method to simultaneously generate energy by combustion and separation of CO₂ from air without the use of additional equipment. In CLC, oxidation and reduction reactions occur in two separate interconnected reactors called Air reactor (AR) and fuel reactor (FR). A metal oxide powder called Oxygen Carrier (OC) circulated between both reactors to transfer Oxygen and heat from Air reactor to Fuel reactor. Designing of fuel reactor is the critical part of CLC unit development. This work focuses on the development and validation of reactor level simulations in Aspen Plus prior to detailed system design. Multiple reactor modules i.e. equilibrium (RGibbs), kinetic (CSTR, PFR), and fluidized-bed modules are implemented to represent the fuel reactor under a range of hydrodynamic and reaction control assumptions. Several heterogeneous reaction formalizations are incorporated including global equilibrium, power law and shrinking core model enabling a systematic assessment of chemical and diffusion-controlled regimes. Kinetic parameters have already been reported in literature for elementary reactions that may occur during OC reduction. Simulated outputs, including species distributions, methane conversion, and oxygen-carrier redox behavior, are quantitatively compared against experimental data to evaluate predictive accuracy and identify governing mechanisms. This work found convenient way to simulate fuel reactor in Aspen plus with reasonable accuracy. The validated model provides the basis for subsequent reactor and system design of the 10 kW CLC prototype.

Keywords: Chemical looping combustion, Air Reactor, Fuel Reactor

Experimental Evaluation and Predictive Modelling of Biopolymer-Based Drilling Fluids under Simulated HPHT Conditions

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Drilling fluids used in HPHT wells often lose rheology and fail to control fluid loss due to thermal degradation of conventional additives. This study evaluates Okra mucilage, a locally available biopolymer in Pakistan, tested individually and in blend with Xanthan Gum, to determine whether these systems can improve thermal stability, rheology, and filtration under HPHT conditions. Four drilling fluid systems were prepared: base mud, Okra-based, Xanthan-based, and an Okra-Xanthan blend. Laboratory tests were conducted up to 120°C to measure plastic viscosity, yield point, gel strength, and fluid loss, followed by thermal aging in an oven. Empirical correlations, including Arrhenius degradation and viscosity-temperature relationships, were applied to predict high-temperature performance beyond laboratory limits. Comparative analysis was performed to assess differences between single-biopolymer and blended formulations. Okra-based fluids exhibited improved rheological and filtration behavior over base mud, with plastic viscosity increasing from 10.5 cP to 11.4

cP and yield point from 4.28 to 6.1 lb/100ft². Fluid loss decreased by 8-12% with reduced filter cake thickness. The Okra-Xanthan blend further enhanced thermal stability, improving the YP/PV ratios from 0.40 to 0.50. Predictive modelling showed the blended system retaining over 70% of its viscosity at 200-220 °C. These outcomes indicate that Okra-based formulations can maintain functional stability under simulated HPHT conditions while utilizing low-cost local materials. This study introduces Okra mucilage as a sustainable, locally sourced drilling fluid additive suitable for HPHT environments. The combined use of Okra and Xanthan Gum demonstrated a cost-effective, environmentally friendly approach to strengthening drilling fluid design while supporting both thermal resilience and operational reliability.

Keywords: HPHT drilling fluids; Okra Mucilage; Thermal Stability

Treatment and Resource Recovery from Industrial Paper-Mill Wastewater using Coagulation–Flocculation Coupled with Dissolved Air Flotation (DAF)

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The wastewater from paper recycling industry can be serious threat to the environment owing to the presence of organic and particulate pollutants, reflected in elevated chemical oxygen demand (COD), total suspended solids (TSS) and turbidity. If inadequately treated, the wastewater can cause significant environmental impacts and loss of reusable fibers. In this study, a combined coagulation/flocculation–dissolved air flotation (DAF) process was investigated to improve mill-water treatment performance with a particular focus on fiber recovery and reuse. An optimized concentration of coagulation/flocculation was developed through jar tests using polyaluminium chloride (PAC) as coagulant and polyacrylamide (PAM) as flocculant. The optimized PAC-PAM conditions achieved 84% turbidity removal, 81% TSS removal and 80% COD removal, with the treated water pH adjusted to 7.8. These conditions were then applied to a pilot-scale DAF unit. Under DAF operation, removals increased to 88% for turbidity, 84% for TSS and 88% for COD, while approximately 84% of the suspended solids were recovered as a concentrated, fiber-rich sludge. A paper sheet was produced from this treated sludge showed about 50% higher strength compared with paper made from raw sludge, confirming the good papermaking quality of the recovered fibers. Overall, the findings demonstrate that coupling coagulation–flocculation with DAF can significantly enhance mill-water treatment and enable high-quality fiber recovery, supporting more sustainable and resource-efficient paper-recycling operations.

Keywords: Mill water, Dissolved air flotation (DAF), Chemical oxygen demand (COD), turbidity, Suspended solids (SS)

Integrating Coagulation-Flocculation and Fluidized Ceramic Membrane Filtration for effective treatment of real Industrial wastewater

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The industrial wastewater is extremely difficult to treat due to its complex content of suspended sediments, colloids, natural organic materials, colors, heavy metals, and resistant chemical contaminants. Coagulation–flocculation is a prevalent primary treatment method because it can destabilize colloids and aggregate fine particles, which reduces turbidity significantly. Membrane filtering systems, in particular ceramic membranes, have better chemical resistance, longer lifetime, and higher separation efficiency. In this regard, the coagulation–flocculation process integrated with fluidized ceramic membrane filtration becomes one of the effective hybrid methods to obtain high-quality effluents, thus minimizing membrane fouling. This work assesses the overall efficiency of the coagulation–flocculation pre-treatment followed by fluidized ceramic membrane filtration for treating real industrial wastewater collected from an industrial manufacturing plant. The performance of the succeeding membrane filtering step was greatly enhanced by optimized coagulation–flocculation. Pre-coagulation reduced turbidity, TSS, and colloidal fractions, which then resulted in the reduction of membrane fouling rate by 40–60%. The fluidized ceramic membrane system also showed remarkable removal efficiencies for residual turbidity (>99%), COD (70–90%), color (80–95%), and heavy metals such as Fe, Pb, and Ni. To maintain a constant flux during operation and reduce the need for periodic chemical cleaning, the fluidization mechanism generated uniform abrasive action on the surface of the membrane. SEM and FTIR analyses of membrane surfaces revealed a diminished cake layer deposition and insignificant blockage of membrane pores upon the administration of coagulation prior to filtering. Sludge generated during the coagulation process showed acceptable settling characteristics and was easily separable, thus enhancing efficient solid-liquid separation prior to membrane filtration. This hybrid approach offers better removal of pollutants, higher flux, lower tendency to foul, and reduced operational cost compared to individual treatment systems. Their potential for large-scale industrial applications where reliable processes and high-quality effluents are considered vital is revealed.

Keywords: FTIR, Performance, Removal efficiency, COD

Sustainable Produced Water Treatment in Oilfields of Pakistan Using a Low-Cost Multistage System

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This study focuses on the environmental issues caused by disposing untreated produced water in Pakistani oilfields and introduces a low-cost treatment system designed for safe reuse at the field level. The aim is to reduce freshwater demand, limit pollution, and convert produced wastewater into a usable resource for drilling, reinjection, and other operational needs. The system has three simple, non-electric stages. First mechanical filtration removes sand, silt, and other suspended solids. Second a solar-assisted evaporation unit reduce water volume and salinity only using sunlight. Third, an adsorption unit containing natural materials such as biochar or bentonite captures remaining oil, dissolved chemicals, and odours. Water samples collected before and after each stage are tested for turbidity, TDS, and oil content to assess quality improvement. The treated water is expected to show significant reductions in turbidity, salinity, and hydrocarbon concentration, making it suitable for drilling fluid dilution, dust suppression, and reinjection into depleted formations. Reusing this water can notably decrease freshwater consumption in remote fields where clean water is limited, while also reducing soil contamination and emissions associated with disposal practices. Compared with commercial treatment systems, the proposed approach is cheaper, easy to maintain, and well suited for small/medium-sized oilfields with limited infrastructure. The study indicates that around 5000 bbl. of produced water can be recycled across Pakistan, removing about 3.5 tons of contaminants, improving water clarity by nearly 70%, and cutting treatment costs by roughly 35%. The modular design provides an effective and sustainable method for produced-water management in resource-constrained environments.

Keywords: Produced Water Treatment, Low-cost Multistage System, Sustainable Oilfields Operations

Domestic Wastewater Treatment and Reuse Using a Decentralized System

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In many regions worldwide, particularly in rural and small communities, centralized wastewater treatment systems remain economically and technically unfeasible due to high capital investment, energy demand, and operational complexity. As a result, untreated domestic wastewater is frequently discharged into the environment, posing serious risks to public health and ecosystems. Decentralized wastewater treatment systems (DEWATS) have emerged as a sustainable and appropriate alternative, offering flexibility, low cost, and adaptability to local conditions. This study presents a comparative assessment of

decentralized wastewater treatment technologies with a focus on identifying low-cost and environmentally suitable options for domestic wastewater treatment and reuse in rural settings. Wastewater characterization data reported in existing studies are synthesized to represent typical rural influent conditions. Selected DEWATS technologies are evaluated based on treatment performance, land and energy requirements, operational simplicity, and potential for safe wastewater reuse in accordance with international guidelines. An environment-focused feasibility checklist is also made to help people choose the right technology and make decisions. The analysis highlights nature-based decentralized systems as particularly suitable for rural communities due to their low energy consumption, reduced environmental footprint, and reliable treatment performance. The findings will contribute to sustainable sanitation planning by providing a practical framework for selecting decentralized wastewater treatment solutions that support water reuse, environmental protection, and long-term sustainability.

Keywords: Wastewater, Sustainability, Environment

Treated Mine Water DO optimization to prevent industrial boiler Corrosion

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Industrial boilers are highly susceptible to oxygen-induced corrosion, a problem strengthened when treated mine water abbreviated as TMW is reused as feedwater. Although it meets many quality criteria after conventional mechanical treatment, it often keeps high dissolved oxygen (DO) content and reduces defending capacity, making it chemically aggressive toward boiler materials. This study investigates the comparative effectiveness of sodium sulfite (Na_2SO_3) and potassium sulfite (K_2SO_3) as chemical oxygen scavengers to optimize DO levels in TMW under simulated boiler conditions. The Comprehensive laboratory experiments were performed using an autoclave machine to mimic feedwater environments, DO concentrations were continuously monitored with calibrated DO meters, and corrosion behavior was assessed using weight loss method on carbon steel coupons. Results revealed that TMW contained 7.5 mg/L DO and produced an extreme corrosion rate of 100.2 mm/yr on boiler steel. At stoichiometric doses, sodium sulfite reduced DO to 0.1 mg/L (98.7% removal) with negligible corrosion (0 mm/yr). While potassium sulfite lowered DO to 0.2 mg/L (97.3% removal) with a residual corrosion rate of 0.48 mm/yr, and critical DO threshold of 0.10–0.15 mg/L was identified for the onset of corrosion, while maintaining DO below 0.05 mg/L effectively suppressed measurable damage. These findings confirm the necessity of mixing chemical oxygen scavengers with TMW reuse to ensure safe and efficient boiler operation and conclude that sodium sulfite is the most effective scavenger under the tested conditions, whereas potassium sulfite remains

suitable where sodium restrictions apply. The outcomes provide a scientific basis for selecting sustainable DO control strategies, extending boiler life, reducing operational costs, and supporting water reuse in resource-limited regions.

Keywords: Dissolved Oxygen Removal, Treated Mine Water, Boiler Corrosion, Oxygen Scavengers

Pyrolysis of Mixed Textile Waste for Producing Biofuel

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The rapid growth of the textile industry has resulted in a significant increase in textile waste, posing serious environmental and waste management challenges. Mixed textile waste, which often contains natural and synthetic fibers, is difficult to recycle using conventional mechanical or chemical methods. Landfilling and incineration of such waste lead to land degradation, greenhouse gas emissions, and loss of valuable resources. Therefore, sustainable and efficient waste-to-energy technologies are urgently required. This project focuses on the liquid pyrolysis of 100 tons of mixed textile waste as a viable solution for waste reduction and energy recovery. Pyrolysis is a thermochemical process carried out in the absence of oxygen, which converts textile waste into useful products such as liquid oil, char, and non-condensable gases. The liquid fuel obtained can be utilized as an alternative energy source, while the gaseous products can be reused to support the process energy requirements, improving overall energy efficiency. The primary aim of this project is to evaluate the technical feasibility of processing large-scale mixed textile waste through liquid pyrolysis and to analyze its potential contribution to energy sustainability. Additionally, the project seeks to reduce environmental pollution, minimize landfill dependency, and promote circular economy principles within the textile sector. By integrating chemical engineering principles with sustainable energy practices, this study highlights pyrolysis as an effective approach for managing textile waste while generating value-added energy products.

Keywords: Chemical engineering; Energy stability

Utilization of Natural and Synthetic Coagulants/Flocculants for Paper Fiber Recovery and Treatment of Sundry Wastewater from the Paper Recycling Industry

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Paper recycling renders sundry wastewater with high level of suspended solids, organic and short fibers which are normally lost along with the effluent, and it adds extra cost to treatment and environmental burden. The wastewater treatment was assessed using a synthetic flocculant and a natural polymer

system separately, the primary goal of which was to improve the quality of the effluent and the reusability of the recoverable fibers. Firstly, the primary coagulant was alum along with synthetic polyacrylamide (PAM) as flocculant then the performance was assessed using as amphoteric guar gum as an independent natural coagulant- flocculant system, without alum. Jar tests were also done to optimize dosage in turbidity, suspended solids and COD removal and in capturing fibers in the sludge. During the treatment, approximately 96% turbidity, 97% suspended solids and 90% COD were observed. The guar-only treatment was also compared with amphoteric and showed similar findings showing 96% turbidity removal, 96% suspended solids removal and 90% removal COD removal. Nevertheless, the amphoteric guar was more expensive based on a unit cost in comparison with the alum-PAM system and, thus, was not economically competitive. The fibers produced in the recovered sludge in both schemes were of high quality and could be used in the process of papermaking. In general, the findings demonstrate that amphoteric guar could be used technically as the equal to standard alum-PAM treatment, and it is possible to indicate that alum-PAM becomes more cost-effective in the present circumstances, and polymer-based coagulant/flocculants play the potentially important role in more sustainable paper-recycling activities.

Keywords: wastewater, coagulation, resource recovery, sustainability, paper industry

Textile Wastewater Treatment

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The research work focus on a novel treatment method of a textile wastewater. The textile wastewater usually composed of contaminants including black liquor with high organic matters, chemicals from bleaching section and high TSS due to fillers and fibers. The treatment system comprised of a settling tank, filtration unit, aerobic digester, and flocculation-coagulation unit and a clean water collection tank. The main focus was given on the primary treatment in which inclined channels have been incorporated in the settling tank to enhanced the sedimentation rate of the solid particles, thus to reduce the TSS. A lab scale unit comprising a settling tank with two inclined sections has been designed to carry out experiments.

Keywords: Inclined channels, solid-liquid separation, wastewater

An evaluation of the effectiveness and feasibility of a specific clean in a specific context to mitigate both air pollution and greenhouse gas emissions

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This study examines how effective and practical it would be to deploy solar-powered public transport systems specifically electric buses supported by solar photovoltaic charging infrastructure in Karachi, Pakistan, as a combined approach to reduce both air pollutants (PM_{2.5}, NO_x, SO₂) and greenhouse gas emissions (mainly CO₂). Karachi, a city of more than 16 million residents, suffers from extremely poor air quality and ranks among the most polluted cities globally, due largely to emissions from over 4.5 million registered vehicles, about 60% of which are aging two-stroke engines. The proposed clean-technology solution solar-powered electric buses would capitalize on Pakistan's substantial solar irradiance (5.5–6.5 KWh/m²/day) to displace conventional diesel buses, with the potential to cut CO₂ emissions by 40-60% per bus-km and PM_{2.5} emissions by 80–90%. The study evaluates effectiveness through emission-reduction modeling, health impact assessments, and comparative analyses with international examples such as Shenzhen, China. Feasibility is investigated across technical, economic, policy, and social factors, with net present value (NPV) calculations indicating financial viability when solar panels are subsidized to below PKR 50/Watt. Key obstacles, including grid unreliability and high upfront investment, are addressed through mechanisms like public-private partnerships (PPPs). The study ultimately recommends a pilot deployment of 100 buses along major high-demand routes such as Shahrah-e-Faisal.

Keywords: Greenhouse gases mitigation, Air pollution, Synergies

To Design, Fabrication, and Performance Analysis of an HHO Gas Generation System using Sea Water and Potassium Hydroxide Electrolytes

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The growing environmental concerns caused by greenhouse gas emissions and reliance on fossil fuels require the exploration of cleaner and maintainable energy choices. Among these, oxy-hydrogen gas (HHO) offers a promising solution by upgrading combustion productivity and decreasing hurtful emissions. This study centers on the design, creation, and execution assessment of an HHO gas generation framework utilizing potassium hydroxide (KOH) arrangements and seawater as electrolytes. The essential objective was to create a cost-effective handle for creating HHO gas and evaluate its potential applications, especially in making strides fuel effectiveness in coal-fired control

plants. A 10- inch water channel lodging served as the electrolyzer, prepared with 14 stainless steel plates protects with fiber washers and fueled by a DC supply. Tests were conducted utilizing seawater and KOH arrangements at concentrations of 10 g/L, 20 g/L, 30 g/L, and 35 g/L. Comes about shown that whereas seawater may be a promptly accessible and reasonable electrolyte, it postured challenges due to cathode erosion and scaling, restricting effectiveness. Seawater accomplished a gas generation rate of 0.6 L/min at 5 A, 15 V with 50% efficiency. In differentiate, KOH solutions significantly made strides execution, with the highest stream rate of 0.8 L/min at 30 g/L. However, productivity declined at higher concentrations due to excessive warm. This study illustrates the natural benefits of HHO gas, emphasizing its potential to reduce outflows and preserve freshwater assets by utilizing seawater. Discoveries highlight the significance of tending to warm administration and anode durability to guarantee framework supportability, contributing to cleaner energy arrangements for industrial applications.

Keywords: HHO gas, green energy, sustainability

Study and Analysis of Wastewater from Marble Industry in KP

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The marble industry in KPK generates large volume of wastewater characterized by high suspended solids, elevated alkalinity, dissolved solids, and organic contaminants, primarily originating from cutting, shaping, and polishing processes. Untreated discharge of wastewater contributes to several environmental challenges, including water pollution, soil degradation, deterioration of ground water quality, and increased turbidity in nearby water bodies. This study investigates the physical characteristics of marble wastewater and evaluates an integrated low-cost treatment system designed for small and medium marble units in Peshawar. The experimental setup consisted of two lamella settlers in series followed by a multi-media filtration unit. Wastewater samples were analyzed for turbidity, TSS, TDS, COD, conductivity, and pH across different flow rates ranging from 1-5 L/min. lamella settlers enhanced solid-liquid separation through inclined-plate sedimentation, reducing TSS from initial 10,400 mg/L to 1180 mg/L, while the filtration unit further lowered it to 250 mg/L. turbidity removal was 88%, and COD reduction above 70% at optimal flow conditions. Performance reduced at higher flow rates due to less retention time and hydraulic overload. The unit was constructed using locally available materials, offering affordability, easy operation, and scalability. Treated water meets reuse standards for marble processing, supporting reduced freshwater demand. The system aligns with SDG-6 and SDG-12 by promoting water reuse and sustainable industry practices.

Keywords: Marble wastewater, Lamella settlers, Environmental Sustainability

Detailed case study on the impact of specific air pollutants NO_x and SO_x on human health in a particular region and how climate change exacerbates these effects

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Air pollution poses a significant threat to human health, particularly in rapidly urbanizing regions where industrialization, transportation, and energy production rely heavily on fossil fuels. Nitrogen oxides (NO_x) and sulfur oxides (SO_x) are among the most harmful gaseous air pollutants due to their direct toxic effects and their role in forming secondary pollutants such as particulate matter and ground-level ozone. This case study examines the impact of NO_x and SO_x on human health in a highly populated urban region, focusing on exposure sources, concentration trends, and associated health outcomes. Epidemiological evidence indicates that short-term exposure to NO₂ and SO₂ leads to increased respiratory symptoms, asthma exacerbations, and hospital admissions, while long-term exposure is linked to chronic respiratory diseases, reduced lung function, cardiovascular disorders, and premature mortality. Vulnerable populations, including children, the elderly, and individuals with pre-existing health conditions, are disproportionately affected. The study further analyzes how climate change exacerbates these health impacts by altering atmospheric conditions, increasing temperatures, intensifying heatwaves, and promoting the formation of secondary pollutants such as ozone. Climate-induced extreme events, including floods and prolonged heat stress, also increase population vulnerability and disrupt healthcare systems, compounding pollution-related health risks. The findings highlight the urgent need for integrated air-quality management and climate-adaptation strategies to reduce emissions, protect public health, and build urban resilience against future environmental challenges.

Keywords: Air pollution, climate change, sustainability

Climate-Driven PM_{2.5} Escalation and Health Burden in Karachi, Pakistan: A Public Health Crisis

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Particulate matter with an aerodynamic diameter of 2.5 micrometers or smaller (PM_{2.5}) represents a critical public health threat in Karachi, Pakistan, where average concentrations reach 70-80 µg/m³—substantially exceeding the World Health Organization's annual recommendation of 5 µg/m³. This study investigates the multifaceted impact of PM_{2.5} on human health in South Asia's largest metropolitan area, where rapid urbanization, unregulated industrial expansion, and escalating traffic emissions have created severe air pollution.

Primary PM_{2.5} sources include diesel vehicles, industrial emissions, construction dust, open waste burning, brick kilns, and residential generators, supplemented by secondary formation through photochemical processes. Long-term exposure to elevated PM_{2.5} concentrations correlates with increased prevalence of respiratory diseases such as asthma and chronic obstructive pulmonary disease (COPD), cardiovascular complications, neurological effects, elevated cancer risk, and premature mortality, as evidenced by hospital admission data showing significant increases in respiratory and cardiac admissions during winter smog episodes. Climate change amplifies this crisis by elevating temperatures, reducing precipitation, prolonging drought periods, altering wind patterns, and intensifying heatwaves, factors that collectively enhance secondary aerosol production, impede pollutant dispersion, and increase energy demand. These findings underscore PM_{2.5} as an urgent public health and environmental concern requiring integrated air quality management strategies and climate-adaptive policy interventions in Karachi.

Keywords: PM_{2.5}, Public health, Respiratory diseases

An evaluation of the effectiveness and feasibility of a specific clean technology in a specific context to the promotion of public and non-motorized transport.

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Transportation-related air pollution and greenhouse gas emissions have become critical challenges in rapidly urbanizing cities of developing countries. Lahore, Pakistan, faces severe air quality deterioration largely due to increasing reliance on private vehicles and traffic congestion. This study assesses the effectiveness and feasibility of promoting public transport and non-motorized transport (NMT) as sustainable solutions to reduce urban emissions in Lahore. The analysis reviews existing initiatives, including the Metro Bus Service and Orange Line Metro Train, alongside limited walking and cycling infrastructure. Findings suggest that public transport has contributed to reduced private vehicle use and lower emissions along major corridors, while NMT holds significant potential for short-distance travel with zero emissions. However, infrastructural gaps, safety concerns, fragmented policies, and social preferences for private vehicles limit widespread adoption. Beyond environmental benefits, promoting public and non-motorized transport offers co-benefits such as improved public health, energy efficiency, and social equity. The study concludes that integrated transport planning, targeted investment, and public awareness are essential to making sustainable urban mobility both effective and feasible in Lahore and similar developing cities.

Keywords: Public Transport, Non-Motorized Transport, Urban Air Pollution

Preparation and analysis of a solid hybrid fuel comprising coal dust and kikar waste

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The research work aims to prepare a solid hybrid fuel at a by combining coal dust with Kikar (*Prosopis juliflora*) biomass waste. The objective is to formulate a cost friendly, environmentally improved and resource efficient fuel by integrating two locally abundant yet underexploited materials coal dust, generated during coal extraction and handling contains high energy potential but poses environmental, safety and disposal concerns. Kikar, an invasive woody plant species serves as a renewable biomass source with a calorific value typically between 15000 and 19000 kJ/kg. The hybrid fuel benefits from the reliability and energy density of coal while integrating the low-sulfur content and near carbon-neutral nature of biomass research on coal–biomass co-firing indicates significant reductions in emissions such as carbon monoxide, sulfur oxides and nitrogen oxides in comparison with the use of coal alone. This study promotes waste-to-energy conversion, decreases reliance on conventional fossil fuels, promotes renewable energy initiatives and ecological management in Pakistan. Furthermore, the project is directed at optimizing operational parameters including blend composition, moisture levels and densification conditions to achieve optimal fuel efficiency and combust performance.

Keywords: Solid hybrid fuel; Renewable energy utilization; Waste recycling.

Evaluating the Effectiveness of Early Warning Systems and Forecasting Models for Predicting Cloudbursts

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Cloudbursts are intense, highly localized rainfall events that can trigger flash floods, landslides, and severe damage—particularly in the mountainous regions of Khyber Pakhtunkhwa (KP), Pakistan. Improving timely, reliable early warning systems (EWS) and forecasting capability is therefore essential to reduce loss of life and property. This study evaluates how well existing forecasting approaches and EWS arrangements support cloudburst risk reduction in KP. The work (i) reviews current EWS and forecasting models used for cloudburst prediction in the region, (ii) assesses the performance and accuracy of selected forecasting/nowcasting approaches using documented historical cloudburst events, and (iii) examines the effectiveness of warning dissemination mechanisms at the community level. Building on hydrometeorological insights from numerical weather prediction (NWP) and radar-based nowcasting—while accounting for known constraints over complex terrain—this paper uses a structured verification and gap-analysis workflow to identify strengths,

limitations, and operational bottlenecks. Expected outcomes include evidence-based findings on forecast skill and lead time, a clearer understanding of EWS performance and communication pathways, and practical recommendations to enhance short-term prediction through better integration of high-resolution models with radar/satellite information, alongside strengthened multi-channel dissemination (e.g., SMS, sirens, local media) and community training and drills.

Keywords: Cloudburst, Early warning systems, Forecast verification

Impact of Specific Air Pollutants and the Hydrological Cycle on Human Health in Lahore, Pakistan, and how Climate Change Exacerbates these Effects

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This case study examines how specific air pollutants principally particulate matter (PM₁, PM_{2.5}, and PM₁₀) interact with the hydrological cycle to affect human health in Lahore, Pakistan, and how climate change intensifies these impacts. Using field measurements collected at a canal adjacent urban sampling site during winter 2018–2019, together with meteorological records and published monitoring data, the study quantifies daily and monthly PM concentrations and evaluates their relationships with temperature, relative humidity, wind speed, and precipitation. Results show persistently elevated PM levels (mean PM_{2.5} \approx 183 $\mu\text{g}\cdot\text{m}^{-3}$; PM₁ and PM₁₀ also substantially above WHO guidelines), strong seasonal accumulation during low-wind and inversion conditions, and pronounced reductions in coarse fraction concentrations during heavy rainfall events. The study links PM acting as cloud condensation nuclei and its wet deposition to both short term air quality improvement and longer term transfer of pollutants to surface and groundwater. Health risk discussion highlights increased respiratory and cardiovascular morbidity, potential waterborne disease risk after extreme hydrological events, and localized problems such as fluorosis linked to water quality. Finally, the paper synthesizes policy and infrastructure oriented recommendations strengthened enforcement, enhanced monitoring, sustainable urban transport, improved drainage, and climate adaptive planning to mitigate combined air water health risks. These findings underscore that integrated air and water management, informed by high resolution monitoring and climate aware policy is essential to protect public health in rapidly urbanizing South Asian megacities.

Keywords: Particulate Matter (PM₁, PM_{2.5}, PM₁₀), Hydrological Cycle Interaction, Climate Change Impacts

Degradation of Persistent Organic and Fluorinated “Forever” Chemicals via TiO₂-Based Advanced Photocatalysis in Aqueous Systems

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Per and polyfluoroalkyl substances (PFAS) are emerging “forever chemicals” of increasing concern in Pakistan due to their persistence, mobility and resistance to conventional treatment. Short-chain PFAS (e.g., PFBA, TFA) contaminate 96% of Pakistan's surface water and 53% of groundwater, driven by textile mill discharge, yet conventional treatment removes <10%. This work investigates a green photocatalytic route for degrading short-chain PFAS using a bimetallic heterojunction supported on TiO₂, synthesized entirely in aqueous media through urea-assisted deposition–precipitation combined with plant-extract reduction. The process employs locally available *Moringa oleifera* and *Azadirachta indica* extracts as dual-function reducing and capping agents, avoiding toxic reductants and organic solvents and aligning with circular-economy principles for sustainable process industries. Controlled pH elevation via urea hydrolysis at 85–90 °C promotes homogeneous nucleation of nanoscale metal oxide domains directly on anatase TiO₂, improving dispersion and interfacial contact relative to conventional impregnation methods. The resulting heterojunction is designed to couple Schottky-type electron trapping with Type-II band alignment, narrowing the effective band gap (target ~2.6–2.8 eV) and enhancing charge separation and near-UV/visible-light utilization for PFAS defluorination. Batch tests show 75–85% PFBA/TFA degradation in 6h under 395 nm light (vs <30% bare TiO₂), with 36–50% fluoride release confirming mineralization. Reusability: stable over 5 cycles. Solar CPC reactor design: \$0.30/m³ (vs \$3–10/m³ alternatives). Green synthesis using local biomass, no toxic reductants, scalable, and compatible with industrial wastewater—directly addressing Pakistan's PFAS crisis. The study demonstrates that green-synthesized TiO₂-based heterojunctions can deliver substantially improved PFAS removal over bare TiO₂, with a synthesis route that is scalable, low-hazard and compatible with industrial wastewater treatment.

Keywords: PFAS Degradation, Advance Oxidation Process (AOP), Bimetallic Heterojunction, Persistent Organic Pollutant, Advanced Photocatalysts, Green Synthesis, Sustainable Wastewater Treatment., Plant-Based Reduction.

Circular Economy Approach to Utilize Agriculture & Paper Waste to DRR & CCA

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This research investigates an approach to a data-driven circular economy that transforms the rice husk-based waste into low-carbon consumer products and evaluates its potential pros from worldwide production scales down towards a local pilot in KPK, Pakistan. According to the Food & Agriculture Organization (FAO), globally, the annual production of Rice husk is estimated to be ~543 million tonnes in 2024/25, implying a vast biomass of husk availability in worldwide. Although in Pakistan, the rice sector remains vital: total production of rice husk in the record of 2023-24 is about 9.9 million tonnes, whereas the expansion of the cultivated area is roughly 3.637 million hectares. As most national rice output comes from major provinces, the meager province includes KPK, a contribution of 2 per cent production nationwide. While its historical production has been modest, according to a study report, the aftermath survey of KPK contributed ~1.5 per cent of national rice output. Applying this context, the research uses Material-Flow analysis (MFA) for the estimation of total annual rice-husk yield (R) and defines the realistic diversion of fraction (u) towards production of bio-composite goods instead of burning. Whereas Life-cycle carbon accounting (LCA) estimates the total potential of CO₂-equivalent reductions by the substitution of conventional materials with rice-husk products. A simple cost-benefit economic model calculates the production cost, local income generation, and market price. For the local pilot in KPK, the study shows that the number of feasible products can be made. Potential CO₂ savings and the expected income it could generate for locals. The overall research identifies a practical model of how even diverting a fraction of rice-husk waste can yield measurable economic and social gains. This model guides policymakers and local actions to support climate resilience, the reduction of disaster risk, and sustainable livelihoods.

Keywords: Rice Husk Utilization, Circular Economy, Material Flow Analysis (MFA)

Mineralogical and Chemical Investigation of the Minerals Potential Area of Chitral for Critical Elements and Rare Earths Elements

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The importance of mineralogical investigation of metallic ore deposits is continuously increasing due to the increasing demand for metallic minerals worldwide. The proper mineral investigation for mineralogy and chemical composition needs to be carried out for selecting appropriate processing technique for the beneficiation of the ore according to the market demand. The purpose of this study is to carry out detail mineralogical investigation of the metallic ore deposit of Chitral, Pakistan, necessary for selecting the most appropriate processing method. Nagir situated on the right bank of Chitral River at an elevation of 4592 ft connected with suspension bridge with Mirkhani-Chitral road. Most promising antimony, copper, gold and silver prospects exist on the right bank of Chitral River continuously running from Nagir to Arindo. The mineralization is named Greenstone formation of Triassic age with thickness of over 2000 m and length of 25 km and contains intrusions of younger acidic rocks. Samples collected from the minerals potentials areas of the mineralized zone were tested in Standard Global Services (SGS) Laboratory Karachi for chemical analysis. The samples were further tested for re-verification of the results at SGS Laboratory Canada. The average chemical composition of the ore mineral were Cu 10.31%, Fe 11.87%, Au 0.11 ppm, Ag 1221.5 ppm and Rare Earths Elements (REEs) 5.3 ppm. Results analysis of the samples confirm that the mineralization has high grade copper, gold, silver, iron, antimony with anomalous amount of lead, zinc and traces of alumina, Calcium Oxide, Magnesium Oxide, Nickel and Rare Earths Elements. Close examination of polished surface and thin sections study of ore samples confirm that ore mineralogically the deposit consists of chalcopyrite CuFeS_2 with associated gold and silver while chief gangue mineral is andradite garnet $\text{Ca}_3\text{Fe}_2(\text{SiO}_4)_3$.

Key words: Mineralization, Beneficiation, Chalcopyrite, Andradite Garnet, Rare Earth elements.



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