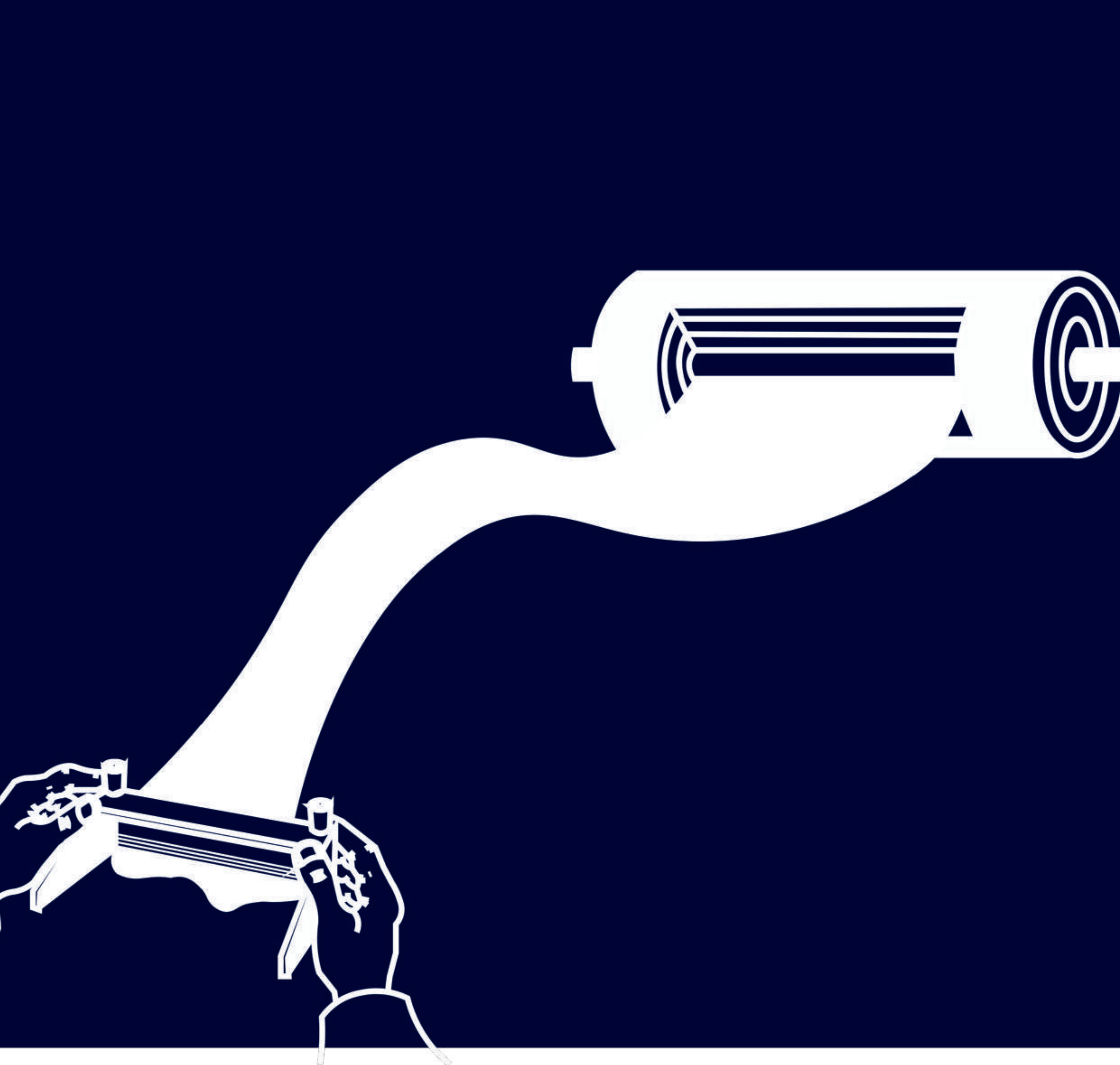

ICMS 2026

International Conference on Cooling and Membrane Separations

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Welcome Message

Faheem Hassan Akhtar

Conference Chair

Welcome to the International Conference on Cooling and Membrane Separations (ICMS 2026). It is our great pleasure to host you in Lahore, Pakistan, as we bring together leading researchers, industry professionals, and emerging scientists from around the world.

ICMS 2026 serves as a dynamic platform for the exchange of knowledge and ideas at the forefront of cooling technologies and membrane-based separation processes. The conference aims to foster meaningful dialogue, highlight cutting-edge innovations, and strengthen collaborations that address pressing global challenges in energy efficiency, environmental sustainability, and advanced process engineering.

We sincerely appreciate the contributions of our distinguished speakers, presenters, and participants whose dedication continues to advance this vital field.

Thank you for being part of ICMS 2026. We wish you an insightful, engaging, and rewarding conference experience.

Dr. Faheem Hassan Akhtar
Conference Chair

Plenary Speakers

Some Surprising Properties of Composite Membranes

Abstract

GMT Membrantechnik, founded in 1995 in Rheinfelden, Germany and now part of the Borsig Group, develops membranes and modules for gas and organic vapor separation, operating in industrial plants worldwide for recovery of valuable or harmful components. Emerging applications include carbon capture and organic solvent nanofiltration. This presentation highlights unexpected transport phenomena in composite membranes, including enhanced selectivity from low-selectivity layers, increased flux upon adding resistance layers, and directional transport asymmetry. Finally, the work examines whether such asymmetric behavior challenges the second law of thermodynamics, discussing its physical origins and limitations.

Prof. Klaus-V. Peinemann

GMT Membrantechnik GmbH, Germany

Prof. Klaus-Viktor Peinemann is a globally recognized pioneer in membrane science whose work has profoundly influenced the development of advanced separation technologies. His landmark contributions to thin-film composite membranes, nanostructured materials, and organic solvent nanofiltration have enabled highly efficient and sustainable separation processes. He is also the Emeritus Professor of Chemical Engineering at KAUST.

Plenary Speakers

Membranes from biopolymers: why and how

Abstract

This lecture will explore the potential of membranes developed from polymers produced via biotechnological processes. The need and opportunity to replace polymers derived from fossil fuels will be discussed, taking into account the need to develop new membranes that meet requirements for flux, selectivity and stability. In particular, the issues of stability under operating conditions and biodegradability upon disposal will be addressed and discussed

Prof. João Crespo

NOVA School of Science and Technology
Portugal

Prof. Crespo is Professor of Chemical Engineering at NOVA School of Science and Technology and a leading expert in membrane process engineering. His research spans membrane bioreactors, pervaporation, and advanced separation systems, with applications in water, food, and bioprocessing. He also serves on the editorial boards of major journals, bridging fundamental science with sustainable industrial solutions.

Plenary Speakers

Sustainable Membrane Fabrication: Green Solvents, Biopolymers and Circular Approaches

Abstract

Membrane fabrication is predominantly solution-based, relying largely on fossil-sourced polymers and solvents, highlighting the need for sustainable alternatives. This presentation explores green solvents such as thymol for polyetherimide (Ultem) and polyimide (Matrimid) membranes, along with bio-based solvents like limonene and pinene. Bio-based polymers including cellulose, lignin, and poly (ethylene furanoate) (PEF) are investigated for membrane preparation and separation applications. Membrane performance is evaluated in gas and liquid separations, supported by detailed life cycle assessment comparing PEF and PET. Finally, circular approaches such as polymer conversion-regeneration, dynamic crosslinking, and vitrimers are discussed.

Prof. Suzana Nunes

King Abdullah University of Science and Technology (KAUST), KSA

Prof. Suzana is a professor of chemical and environmental science and engineering at King Abdullah University of Science and Technology (KAUST) in Saudi Arabia. In recognition of her contributions to physical sciences and membrane technology, Nunes was named the international 2023 L'Oréal-UNESCO For Women in Science Laureate for Africa and the Arab States. She is a Fellow of the São Paulo Academy of Sciences, the Royal Society of Chemistry (UK), the North American Membrane Society, and an honorary member of the European Membrane Society.

Plenary Speakers

Membrane opportunities in biorefineries

Abstract

The transformation of pulp and paper mills into lignocellulosic biorefineries is key to achieving a circular and resource-efficient bioeconomy. This presentation highlights how membrane technology enables selective, low-energy recovery of valuable components such as lignin, hemicelluloses, and chemicals from biomass streams. In kraft pulping, ultrafiltration and nanofiltration enhance lignin recovery and improve energy efficiency, supported by optimized cleaning strategies. In sulfite pulping, membrane filtration reduces COD and fouling, improving process performance. Overall, membrane-based separations support resource recovery, process intensification, and reduced environmental impact.

Prof. Frank Lipinzki

Lund University, Sweden

Prof. Lipinzki specializes in membrane-based separation processes for food, biotechnology, water, and biorefinery industries. He leads the Industrial Membrane Process R&D Centre and currently serves as President of the European Membrane Society, contributing to international research and sustainability initiatives.

Plenary Speakers

Polyelectrolyte Complexes as versatile building blocks for advanced functional membranes

Abstract

Polyelectrolytes, when oppositely charged, form insoluble polyelectrolyte complexes with tunable properties such as ionic crosslink density, charge, and swelling. This presentation highlights how such control makes them highly promising membrane materials with precisely adjustable separation performance. Recent breakthroughs include asymmetric polyelectrolyte multilayer coatings forming ultra-thin (4–5 nm) active layers with excellent pollutant removal and controlled ion retention. Additionally, aqueous phase separation enables fully water-based fabrication of membranes for microfiltration to nanofiltration. Finally, hot-pressing techniques produce ion exchange membranes with unique selectivities, while dense complexes also serve as recyclable oxygen barrier coatings.

Prof. Wiebe M. de Vos

University of Twente, Netherlands

Prof. De Vos is a professor at the University of Twente (MESA+ Institute), where he leads research on advanced membrane coatings and surface chemistry. His work focuses on developing innovative membranes with properties such as anti-fouling, virus inactivation, and highly selective separations for sustainable water treatment.

Plenary Speakers

Developing membrane techniques for energy-efficient desalination

Abstract

Water scarcity has emerged as a major global challenge. Desalination provides a viable route for producing freshwater from seawater; however, most membrane-based techniques, particularly reverse osmosis (RO), are highly energy intensive. After identifying the key factors contributing to the high operational costs of RO, recent advances in RO membrane modification aimed at mitigating these limitations will be discussed. In comparison, forward osmosis (FO) desalination offers greater inherent energy efficiency, yet the development of high-performance draw materials is still underdeveloped. Smart draw materials have demonstrated strong potential to enhance FO desalination performance significantly. Finally, the thermally driven membrane distillation (MD) process will be briefly examined, given its ability to operate under low-temperature and low-pressure conditions.

Prof. Sheng Dai

University of Leeds, UK

Prof. Dai is a Professor of Chemical Engineering and Head of the School of Chemical and Process Engineering at the University of Leeds. His research focuses on functional materials and advanced membranes for separation, clean energy, water treatment, and biotechnology applications.

Plenary Speakers

Assembly of Layer-by-layer nanofiltration membranes

Abstract

The removal of organic micropollutants (MPs) from water is increasingly important due to stricter regulations and environmental concerns. Layer-by-Layer (LBL) nanofiltration membranes offer a sustainable, high-performance solution, often outperforming conventional membranes. However, key challenges remain, including limited understanding of LBL assembly thermodynamics, kinetics, and membrane design principles. This presentation highlights recent breakthroughs in understanding LBL membrane properties and their interactions with MPs. Novel models for assembly and separation mechanisms are introduced, providing new insights into membrane design. Finally, future perspectives are presented to guide advancements in this field.

Prof. Tao He

Shanghai Advanced Research Institute, China

Prof. Tao He is a leading researcher in membrane science and serves as Co-Editor-in-Chief of Desalination Journal and Executive Editor of Desalination and Water Treatment. With over 30 years of experience, his research focuses on developing advanced membranes for ion separation, resource recovery, micropollutant removal, and green energy applications.

Keynote Speakers

Dr. Muhammad Wakil Shahzad

Northumbria University, UK

S2Cool: Bridging Research and Industry for Sustainable Cooling at Scale

Dr. Clara Casado-Coterillo

University of Cantabria, Spain

What can be learn of CO_2 selective chitosan composite membrane fabrications for the development of durable electrodes for carbon capture and utilization?

Dr. Luis Francisco Villalobos

University of Southern California, USA

Designing Ion-Selective Polyamide Membranes Using Principles from Biological Ion Channels

Keynote Speakers

Dr. AaMer Ali

Aalborg University, Denmark

Membrane distillation for industrial water treatment: opportunities and bottlenecks

Dr. Qian Chen

Tsinghua University, China

Simultaneously Boosting Freshwater Productivity and Antifouling Efficacy of Membrane Distillation Through In Situ Micro-Bubble Generation

Dr. Xiaohua Ma

Tiangong University, Tianjin, China

Crosslinked polyimide membranes and their derivatives for efficient CO_2 removal from natural gas

Dr. Sungil Jeon

Membrare, South Korea

How MEMBRARE is addressing the global issues of Net Zero and PFAS?

Program schedule

APRIL 08, 2026

RECEPTION & REGISTERATION

8:00 AM - 9:00 AM

SESSION - 1 A

Moderator: Dr. Faheem Hassan Akhtar

9:00 AM - 10:10 AM

9:00 AM - 9:15 AM OPENING REMARKS
Dr. Faheem Hassan Akhtar
Principal Organizer & Assistant Professor, LUMS

9:15 AM - 9:30 AM WELCOME ADDRESS
Rector, LUMS

9:30 AM - 10:10 AM ***Some Surprising Properties of Composite Membranes***
Prof. Klaus-Viktor Pienemann
(Plenary Speaker)

10:10 AM - 10:40 AM **Tea Break & Group Photo**

SESSION - 1 B

Moderator: Dr. Shazia Ilyas

10:10 AM - 02:00 PM

10:40 AM - 11:20 AM ***Polyelectrolyte Complexes as versatile building blocks for advanced functional membranes***
Prof. Wiebe M. de Vos
(Plenary Speaker)

11:20 AM - 11:50 AM ***Simultaneously Boosting Freshwater Productivity and Antifouling Efficacy of Membrane Distillation Through In Situ Micro-Bubble Generation***
Dr. Qian Chen
(Keynote Speaker)

11:50 AM - 12:20 PM ***What can be learn of CO_2 selective chitosan composite membrane fabrications for the development of durable electrodes for carbon capture and utilization?***
Dr. Clara Casado-Coterillo
(Keynote Speaker)

12:20 PM - 12:40 PM ***Membrane-based separation & process optimization for efficient hydrocarbon recovery***
Inamullah
(Invited Speaker)

12:40 PM - 01:00 PM ***Machine Learning Frameworks for Performance Optimization of Multi-Effect Desalination System***
Uzair Ahmad

1:00 PM - 2:00 PM **LUNCH**

SESSION - 2

Moderator: Dr. Saeed Gul / Dr. Abu Bakr

2:00 PM - 5:30 PM

2:00 PM - 2:40 PM ***Membrane opportunities in biorefineries***
Prof. Frank Lipinzki
(Plenary Speaker)

2:40 PM - 3:20 PM ***Assembly of Layer-by-layer nanofiltration membranes***
Prof. Tao He
(Plenary Speaker)

3:20 PM - 3:50 PM ***How MEMBRARE is addressing the global issues of Net Zero and PFAS***
Dr. Sungil Jeon
(Keynote Speaker)

3:50 PM - 4:20 PM ***Bridging Systems thinking and Technology development in the Water-Energy-Food-Climate Nexus***
Prof. Abubakr Muhammad
(Invited Speaker)

4:20 PM - 4:40 PM ***Circular and Sustainable Downstream Processing for Cellular Agriculture: Membrane-Enabled Purification and Green Solvent Strategies***
Dr. Fatima Anjum

4:40 PM - 5:00 PM ***Green-Solvent-Fabricated PVDF Membranes with In Situ FBRM Monitoring for Osmotic Membrane Crystallization***
Syeda Laraib

5:00 PM - 5:30 PM ***Designing Ion-Selective Polyamide Membranes Using Principles from Biological Ion Channels***
Dr. Luis Francisco Villalobos
(Keynote Speaker)

APRIL 09, 2026

SESSION - 3
Moderator: Dr. Maria / Dr. M. Sultan

9:00 AM - 12:20 PM

- **9:00 AM - 9:40 AM** — ***Sustainable Membrane Fabrication: Green Solvents, Biopolymers and Circular Approaches***
  Prof. Suzana Nunes
  (Plenary Speaker)
- **9:40 AM - 10:20 AM** — ***Developing membrane techniques for energy-efficient desalination***
  Prof. Sheng Dai
  (Plenary Speaker)
- **10:20 AM - 10:50 AM** — ***S2Cool: Bridging Research and Industry for Sustainable Cooling at Scale***
  Dr. Muhammad Wakil Shahzad
  (Keynote Speaker)
- **10:50 AM - 11:20 AM** — ***Membrane distillation for industrial water treatment: opportunities and bottlenecks***
  Dr. Aamer Ali
  (Keynote Speaker)
- **11:20 AM - 11:40 AM** — ***A Novel Hybrid Cooling System for Future Sustainability***
  Dr. Muhammad Ahmed
- **11:40 AM - 12:00 PM** — ***Modelling of Bipolar Membrane Electrodialysis for Organic Acid Recovery***
  Muazzam Khalil
- **12:00 PM - 12:20 PM** — ***Defect-engineered MOF-74 gel as a transformative filler for high-performance CO_2 separation membranes***
  Aqib Riaz

12:20 PM - 1:00 PM — LUNCH

1:00 PM - 2:45 PM — **Poster Presentations**
Dr. Ghayour Abbas
Dr. Aamer Ali

SESSION - 4
Moderator: Prof. Basit Yameen

3:00 PM - 5:40 PM

- **3:00 PM - 3:40 PM** — ***Membranes from biopolymers: why and how***
  Prof. Joao Crespo
  (Plenary Speaker)
- **3:40 PM - 4:10 PM** — ***Crosslinked polyimide membranes and their derivatives for efficient CO_2 removal from natural gas***
  Dr. Xiaohua Ma
  (Keynote Speaker)
- **4:10 PM - 4:40 PM** — ***Gatekeepers of Ions: Functionalized UiO66 Multilayers for Selective Separation***
  Ahsan Khan
- **4:40 PM - 5:00 PM** — ***Utilization of Permeate Gas as an Indigenous Fuel Source***
  Tabassam Nafees
  (Invited Speaker)
- **5:00 PM - 5:20 PM** — ***Advanced Polyurethane Membranes: From Structural Tuning to Functionalization for Water Treatment***
  Dr. Shahzad Maqsood Khan
  (Invited Speaker)
- **5:20 PM - 5:40 PM** — ***Chitosan-Polysulfone Composite Membranes for Selective Removal of Heavy Metals***
  Naveed Akhtar

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Moderator: Prof. Irshad Hussain

- **5:40 PM - 6:30 PM** — **Prof. Kauser Abdullah Malik**
  (President, Pakistan Academy of Sciences)

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Nexus between Heat Stress and Students' Well-being: A Sociological Study of Climate Vulnerability in Higher Education Institutions, Punjab, Pakistan

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Haseeb Yaqoob, Muhammad Ahmad Jamil, Muhammad Mehroz, Muhammad Wakil Shahzad (Northumbria University, UK)

CFD-Driven Design and Genetic Algorithm Optimisation of a Mist-Based Indirect Evaporative Cooling System

Nida Imtiaz, Mazlan Abul Wahid, Muhammad Ahmad, Muahmmad Hamid Mahmood, Muhammad Sultan, Muhammad Wakil Shahzad (Universiti Teknologi Malaysia)

Continuous Phase CFD Modeling of an Indirect Evaporative Cooler for Air-Conditioning Applications

Muhammad Hamid Mahmood, Muhammad Sultan, Muhammad Wakil Shahzad (Bahauddin Zakariya University, Multan)

Polyelectrolyte Complex Membranes for Air Dehumidification

Muhammad Hamza Ali Haider, Faheem Hassan Akhtar (Lahore University of Management Sciences)

State-of-the-Art in Desiccant-Assisted Evaporative Cooling for the Development of Greenhouse Air Conditioning Systems

Hafiz Muhammad Umar Raza, Muhammad Sultan, Muhammad Wakil Shahzad (Bahauddin Zakariya University, Multan)

Insights into Applications of Sustainable Indirect Evaporative Cooling Systems for energy-efficient control of temperature and humidity

Muhammad Ali Imran, Muhammad Sultan, Muhammad Wakil Shahzad (Bahauddin Zakariya University, Multan)

Preparation of thin film composite membranes and modules for industrial flue gas separation

Hafiza Aroosa Aslam Khan, Naveed Ramzan, Muhammad Sarfraz (University of Engineering and Technology, Lahore)

Imidazolium Ionic Liquid Modified Cellulose Nanocrystal based Novel Desalination Membranes with Improved Antimicrobial and Antifouling Properties

Noor Ul Sarahat, Hifsa Khalique, Muhammad Muqtasid, Reehana Batool, Mudassir Iqbal (NUST, Islamabad)

A Novel Hybrid Cooling System for Future Sustainability

Muhammad Ahmed, Muhammad Wakil Shahzad, Nida Imtiaz, Haseeb Yaqoob, Muhammad Mehroz (Northumbria University, UK)

Poster Presentations

Upcycling Waste Polyethylene terephthalate (PET) Bottles into High-Performance Aluminum based metal organic frameworks (MOFs) for Sustainable Antibiotic Removal from Water

Beenish Shazadi, Aqeel Ahmad Bazmi, Muhammad Yasin, Mazhar Amjad Gillani, Asim Laeeq Khan (COMSATS University Islamabad, Lahore Campus, Pakistan)

Flexible Bimetallic MIL-88B MOFs for Tunable Transport in Pebax Mixed Matrix Membranes for CO2/CH4 Separation

Hassam Ahmad, Faheem Hassan Akhtar (Lahore University of Management Sciences, Lahore, Pakistan)

Sustainable Cooling to Address Extreme Heat and Occupational Inequality: A Qualitative Study of Gendered and Socioeconomic Vulnerabilities among Textile Workers in Pakistan

Farhana Nosheen, Sadaf Mehmood (Government College University Faisalabad)

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Isha Sameen, Alaa Etaiwi, Takahiko Miyazaki, Kyaw Thu (Kyushu University, Japan)

Modelling of Bipolar Membrane Electrodialysis for Organic Acid Recovery

Muazzam Khalil , Rizwan Ahmed Malik, Muddassir Ali (UET, Taxila)

Isolation and Identification of Anaerobic Thermophilic Quorum Quenching Bacteria for Optimization of Anaerobic Membrane Distillation Bioreactor (An-MDBR)

Zahida Noor, Sher Jamal Khan (National University of Sciences and Technology (NUST))

Investigating halophilic Quorum Quenching Consortium for biofouling control in Anaerobic Forward Osmosis Membrane Bioreactor (An-OMBR)

Sania Abbas, Sher Jamal Khan (National University of Sciences and Technology (NUST))

A Hierarchically Porous Silica Cage Composite for Energy Efficient Air Dehumidification

Ayesha Malik, Faheem Hassan Akhtar (Lahore University of Management Sciences, Lahore, Pakistan)

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Sustainable Desalination via Waste-Derived Thin Film Nanocomposite Membranes with Enhanced Transport and Fouling Resistance

Aroosa Nehal, Aamir Razaq, Asim Laeeq Khan, Muhammad Yasin, Mazhar Amjad Gillani, Beenish Shahzadi, COMSATS University Islamabad, Lahore Campus, Pakistan)

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Scalable synthesis of asymmetric hemodialysis membranes to enhance performance and biocompatibility in flat sheet and hollow fiber configurations
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Modelling of Bipolar Membrane Electrodialysis for Organic Acid Recovery

Muazzam Khalil, Rizawan Ahmad Malik, Muddassir Ali (University of Engineering and Technology, Taxila)

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Data-Driven Design of Hydrophobic Deep Eutectic Solvents for Membrane-Based Separation Systems
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Sumaiya Shamshad, Shazia Ilyas, Faheem Hassan Akhtar (Forman Christian College (A Chartered University), Lahore)

Polyelectrolyte Multilayer-Based Nanofiltration Membranes with Tunable Performance for Target Pollutants
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Poster Presentations

Sustainable Electrocatalysts NiFe2-xCoxO4 (x = 0.0 To 0.8) Oxides and their Composites for Water Splitting

Atif Hussain, Falak Sher (Lahore University of Management Sciences, Pakistan)

Development of nanofiltration membranes utilizing zinc oxide nanoparticles for enhanced antifouling and antibacterial properties

Sadia Tabassum, Shazia Ilyas, Wiebe M. De Vos, Faheem Hassan Akhtar, Rashid Khan(COMSATS University Islamabad, Lahore Campus, Pakistan)

Development of Selective Mixed Matrix Membranes for Separation of Lithium Ions from Simulated Brine Solution

Syed Ahmad Waqas, Bilal Haider, Rafi ullah Khan(University of The Punjab, Lahore)

Zn-Co nanoferrites incorporated polysulfone nanofiltration membranes for wastewater treatment

Kiran Shahzadi, Muhammad Sarfaraz (University of Engineering and Technology, Lahore)

Carbon Capture via Thin-Film Composite Membranes Comprising Polysulfone-Coated Vertically Aligned ZIF-302 Nanoarrays

Hafiza Sidra Nawaz, Aqib Riaz, Muneera Alomar, Muhammad Sarfaraz (University of Engineering and Technology, Lahore)

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Araib Asif, Shazia Ilyas, Jamila Bashir, Asim Laeeq Khan, Faheem Hassan Akhtar, Samina Mehnaz (Forman Christian College (A Chartered University), Lahore)

Enhanced Wastewater Treatment Using Functionalized Graphitic Carbon Nitride (g-C3N4) Based Composite Membrane

Muhammad Zia Ul Haq, Sikandar Rafiq (University of Engineering and Technology, Lahore)

Investigation of Metal Phthalocyanines (Co, Ni, Cu) as Efficient Electrocatalysts for Nitrate Reduction to Ammonia

Sania Zahid Dogar, Ifra Bashir, Saoud ul Hassan, Ali Rauf (Lahore University of Management Sciences, Pakistan)

Seasonal Dynamics of PM2.5 and Associated Non-Carcinogenic Health Risks for Adults and Children

Khadija Shanzay Mustafa, Shahana Khurshid, Sayeeda Hafsa Masood (Lahore University of Management Sciences, Pakistan)

Poster Presentations

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Ahmad Raza, Namra Hussain, Arooba Rahat, Saad Sarwar, Irshad Hussain (Lahore University of Management Sciences, Pakistan)

Desalination of Sea Water using Graphene and bio-composite PVC membranes by immersion method

Mamoona Alam, Manahil Sajjad, Zainab Noor, Shabahat (Shaheed Benazir Bhutto Women University, Peshawar, Pakistan)

Development of Alternate Perfluoromembranes for the safe transportation of hydrogen Peroxide

Maham Makhdoom, Aniza Nasir, Faheem Hassan Akhtar (Lahore University of Management Sciences, Pakistan)

Enhanced degradation of Ranitidine using PVDF@CoFe2O4 catalytic membrane: Optimization of Co:Fe ratio

Ayesha Nasir, Faheem Hassan Akhtar (Lahore University of Management Sciences, Pakistan)

Chitosan-polysulfone composite membranes for selective removal of heavy metals

Naveed Akhtar, Beata Malczewska (Wrocław University of Environmental and Life Sciences, poland)

Nanoconfined catalytic membranes for emerging pharmaceutical contaminants (PCs degradation)

Nimra Anis, Faheem Hassan Akhtar (Lahore University of Management Sciences, Pakistan)

Scalable synthesis of PET-derived mixed matrix membranes for enhanced carbon dioxide separation

Samia Farrukh, Faheem Hassan Akhtar (Lahore University of Management Sciences, Pakistan)

Environmental friendly membrane for efficient removal of microplastics

Muhammad Haris, Karishma Jain, Sanjay R. Dhakate, Nicky Eshtiaghi, Nasir Mahmood (RMIT University, Melbourne, Australia)

ABSTRACTS FOR POSTER PRESENTATIONS

Nexus between Heat Stress and Students' Well-being: A Sociological Study of Climate Vulnerability in Higher Education Institutions, Punjab, Pakistan

Dr. Sadaf Mahmood 1[a]* *(Presenting Author),* Dr. Farhana Nosheen 2[b], Dr. Muhammad Atif 3[c], Dr. Muhammad Idrees 4[d]

[a] Affiliation 1 Department of Rural Sociology, University of Agriculture, Faisalabad, Punjab, Pakistan

[b] Affiliation 2 Department of Home Economics, Government College University, Faisalabad, Punjab, Pakistan

[c] Affiliation 3 Department of Rural Sociology, University of Agriculture, Faisalabad, Punjab, Pakistan

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Abstract:

Globally, there is an increase in temperature, and continuous heatwaves have increased the environmental and heat stress in South Asian countries such as Pakistan. The heat pressure is impacting human productivity and the health of the people. The data collection sample was University students (youth), which is a highly vulnerable but not well-studied group at risk of heat stress due to climate This paper analyses the nexus that exists between heat stress and student well-being in post-secondary institutions, with special focus on physical well-being, psychological distress, cognitive abilities, and academic success. The paper also examines how socioeconomic status, gender, housing conditions, and access to cooling devices influence the development of the differences in vulnerability and adaptive capacity. The quantitative research design was adopted. The data was collected from the universities of South Punjab (Multan) and Central Punjab (Faisalabad) with the help of a well-structured questionnaire through Google Form. The quantitative survey data results showed that the sample has a significant gender distribution, with female respondents having 63.5% of respondents as opposed to 36.5% male respondents. The piece is very pertinent to the Gender Equality and Social Inclusion (GESI) scoping framework, where it is required to have a gendered interpretation of climate effects. 90.3% students confirm that their classrooms lacked AC. 70% of the students are often exposed to the peak heat during travel to their institutions, whereas 57% of the students stated that they don't have cooling facilities at their homes, which shows the overall trend of the society. The experiences of thermal discomfort and coping mechanisms among students are reported. It is anticipated that the findings will offer empirical data on educational disruption due to climatic conditions and point out inequalities in adaptive resources as well as provide policy recommendations on heat adaptation strategies in institutions of higher education.

Keywords: Heat stress, students' well-being, higher education institutions, social inequalities, climate vulnerability

Performance Evaluation of a Novel Ultrasonic Mist-Assisted Indirect Evaporative Cooling System

Haseeb Yaqoob[a],*, Muhammad Ahmad Jamila, Muhammad Mehroza, Muhammad Wakil Shahzada

a Mechanical & Construction Engineering Department, Northumbria University, Newcastle Upon Tyne NE1 8ST, UK

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Abstract:

This study examines the performance of a novel indirect evaporative cooler (IEC) connected to an ultrasonic mist generator to improve cooling efficiency. Traditional IEC systems rely on wetted surfaces for the evaporative process, which often encounter issues such as uneven water distribution, low evaporation rates, and mineral scaling. Ultrasonic humidification produces uniform water droplets that evaporate quickly, resulting in more consistent and effective humidification of the working air stream. The experimental setup was designed to evaluate the system's performance under a variety of operating parameters. The important performance parameters, including temperature drop and coefficient of performance (COP), have been recorded and examined. The system efficiently exchanged heat between the primary and secondary air streams, resulting in a maximum temperature reduction of 20 °C. Furthermore, the system achieved a high COP of 33, demonstrating the ultrasonic humidification system's minimal energy consumption when compared to traditional pumping systems. The installation of the ultrasonic mist generator not only enhanced thermal performance but also helped conserve water by generating mist only when needed, resulting in lower total water consumption. These findings indicate that this improved IEC arrangement has enormous potential as a sustainable and energy-efficient option for space cooling, particularly in hot and dry climates where water supply and energy efficiency are crucial. The work contributes to research supporting the application of advanced humidification methods in evaporative cooling systems for future generations.

Keywords: Indirect evaporative cooler; Ultrasonic mist generator; Sustainable cooling; Humidification

CFD-Driven Design and Genetic Algorithm Optimisation of a Mist-Based Indirect Evaporative Cooling System

Nida Imtiaz[a]*, Mazlan Abdul Wahid[a]**, Muhammad Ahmad[b], Muhammad Hamid Mahmood[c], Muhammad Sultan[c], Muhammad Wakil Shahzad[b]

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[b] Mechanical and Construction Engineering Department, Northumbria University, Newcastle Upon Tyne NE18ST UK.

[c] Department of Agricultural Engineering, Bahauddin Zakariya University, Multan 60800, Pakistan

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Abstract:

The rapid increase in global cooling demand and the environmental impact of conventional mechanical vapour compression (MVC) systems necessitate the development of energy-efficient and low-carbon cooling technologies. Indirect evaporative cooling (IEC) offers a promising alternative; however, conventional nozzle-based IEC configurations suffer from non-uniform evaporation, hydraulic complexity, and limited thermal performance. This study presents a CFD-driven design and genetic algorithm (GA) optimisation framework for a novel mist-based IEC system and its translation into a physical prototype.

A three-dimensional multiphase CFD model was developed to simulate airflow distribution, droplet evaporation, heat and mass transfer, and pressure drop characteristics within the IEC heat exchanger. Parametric analysis was conducted for heat exchanger frontal areas ranging from 200 × 200 mm to 500 × 500 mm and channel gaps between 1 mm and 5 mm. A GA-based multi-objective optimisation strategy was implemented to maximise cooling effectiveness and heat transfer rate while minimising pressure losses and auxiliary power consumption. Optimisation results identified a 3 mm channel gap as the optimal configuration, providing the best trade-off between enhanced evaporation efficiency and acceptable pressure drop. The optimised mist-based IEC achieved a cooling effectiveness of up to 0.82, representing approximately 10% performance improvement compared to nozzle-based configurations. The predicted pressure drop was reduced by 18–25%, while the elimination of pump and nozzle circulation subsystems decreased parasitic energy consumption by 30–35%.

Based on the optimised CFD design, a 500 W laboratory-scale prototype was fabricated and experimentally evaluated. The prototype demonstrated stable outlet air temperature reduction

of up to 20-23°C, consistent with numerical predictions, and achieved a system coefficient of performance (COP) exceeding 20, confirming the high energy efficiency of the proposed configuration. The simplified mist-based architecture further reduced system complexity, capital cost, and maintenance requirements. The proposed CFD–GA design methodology provides a scalable pathway for developing high-performance, low-cost, and climate-resilient evaporative cooling systems suitable for decentralised cooling applications and future sustainable cooling infrastructure.

Keywords: Mist-based IEC, Nozzle-based IEC, Low-energy cooling, Sustainable air conditioning, Evaporative cooling systems

Next-Generation Indirect Evaporative Cooling: Experimental Validation of a Mist-Based Approach

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Abstract:

Comfort cooling has transitioned from a luxury to a critical global necessity, driven by rising temperatures, rapid urbanisation, and increasing exposure to extreme heat. Currently, more than 30% of the global population experiences hazardous heat conditions for over 20 days annually, a figure projected to exceed 70% by the end of this century. At the same time, global air-conditioning stock is expected to surpass 5 billion units by 2050, significantly increasing electricity demand and carbon emissions. Conventional cooling technologies remain dominated by mechanical vapour compression (MVC) systems, which are energy intensive and reliant on high global warming potential refrigerants, highlighting the urgent need for sustainable alternatives.

Indirect evaporative cooling (IEC) offers a low-energy, environmentally benign cooling solution by enabling sensible cooling through water evaporation in wet channels without adding moisture to the supply air. However, conventional nozzle-based IEC systems are constrained by auxiliary pumping requirements, complex water distribution networks, maintenance challenges, and limited thermal performance. In this study, a novel mist-based IEC configuration is developed and experimentally evaluated against a conventional nozzle-based IEC system to address these limitations.

A laboratory-scale 500W prototype was designed, fabricated, and tested under controlled operating conditions to evaluate thermal performance, cooling effectiveness, and system efficiency. Experimental results demonstrate that the mist-based IEC achieved approximately 10% higher cooling performance compared to the nozzle-based configuration. Moreover, the mist-based design enabled the elimination of the pump and nozzle circulation circuit, significantly simplifying system architecture while reducing parasitic energy consumption, maintenance requirements, and overall capital and operational costs. The simplified mist-based configuration

also improved water–air contact efficiency, enhanced evaporation uniformity, and delivered more stable outlet air temperatures. These advantages position mist-based IEC technology as a promising low-cost, energy-efficient cooling solution for decentralised applications, particularly in hot and arid climates. The findings provide a strong foundation for scaling IEC systems and integrating them with hybrid cooling architectures for next-generation sustainable cooling infrastructure.

Keywords: Mist-based IEC, Nozzle-based IEC, Low-energy cooling, Sustainable air conditioning, Evaporative cooling systems

Continuous Phase CFD Modeling of an Indirect Evaporative Cooler for Air-Conditioning Applications

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Abstract:

Indirect evaporative cooling is a sustainable and energy-efficient technology for air-conditioning applications particularly in hot and dry climates. The study presents a continuous phase computational fluid dynamics (CFD) model to analyse the thermal performance of an indirect evaporative cooler. The evaporative process is modeled using species transport approach considering air and water vapor as a continuous mixture without discrete droplet tracking. A three-dimensional model of the cross-flow IEC channels is developed for simulations under steady-state conditions. The performance of cross-flow IEC with varying channel sizes (400mm-1100mm) is simulated in ANSYS (Fluent). The related governing equations for mass, momentum, energy, and species transport are modeled under set boundary conditions. The influence of inlet air properties on outlet air temperature, pressure drop and associated cooling performance is investigated. The simulation results revealed the temperature drop about 10°C at higher inlet air temperature. The temperature drops increase by increasing the channel size from 400×400 mm to 700×700 mm but the increment is not found substantially high. The CFD analyses confirmed that the channel size and inlet air flow conditions significantly influence the cooling efficiency of IEC. Increasing the exchanger size may enhanced the thermal performance but also led to higher pressure drops and longer computational times. The 400 mm configuration is primarily considered for the development of IEC. It is due to the envisaged balance between system cooling effectiveness and economy. The study findings provide the basis for optimized design of IEC for air-conditioning applications.

Keywords: CFD, Continuous phase modeling, Indirect evaporative cooler, Design parameters, Evaluation

Polyelectrolyte Complex Membranes for Air Dehumidification

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Abstract

Polyelectrolyte complex (PEC) membranes have emerged as promising materials for air dehumidification because of their hydrophilic nature, tunable structure, and selective water vapor transport properties. In this study, PEC membranes were fabricated using an aqueous phase separation method, which is both simple and environmentally friendly. The fabricated membranes were evaluated in both single-gas and mixed-gas dehumidification setups. The membranes were fabricated by casting a dope solution consisting of polystyrene sulfonate (PSS-Na) and polyethyleneimine (PEI) onto a glass substrate, followed by immersing the cast solution into an acetate buffer bath with a pH value of 4. In addition, some of the PEC membranes were fabricated by heating the cast dope solution prior to immersion in the acetate buffer solution. The heat treatment improved the selectivity and mechanical strength of the membranes while reducing their permeability. Overall, the PEC membranes exhibited high permeability but relatively low selectivity, likely due to the presence of nanopores within the membrane structure, with a maximum permeability of 6.0×10^5 barrer. Under mixed-gas conditions, the membranes demonstrated a maximum permeance of 300 GPU and an H_2O/N_2 selectivity of 51. In summary, the findings of the study highlight the strong potential of PEC membranes for air dehumidification applications.

Keywords: Polyelectrolyte complex membranes, air dehumidification, Hydrophilic, porous structures, aqueous phase separation.

State-of-the-Art in Desiccant-Assisted Evaporative Cooling for the Development of Greenhouse Air Conditioning Systems

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Abstract:

Population growth poses a significant challenge for modern agro-energy security initiatives, particularly in the context of limited water, food, and land resources. The innovative approach of greenhouse farming can be a sustainable solution to this issue to some extent. The potential of greenhouse farming remains constrained, particularly in hot and arid climates, due to challenges in maintaining optimal temperature and humidity conditions. Conventional vapor compression air-conditioning (VCAC) systems are widely used for greenhouse cooling, but their high electrical energy demand and associated greenhouse gas emissions limit their suitability for sustainable agricultural applications.

In this study, two energy-efficient air-conditioning configurations are proposed and evaluated for greenhouse temperature and humidity control: (i) a desiccant air-conditioning (DAC) system, and (ii) an M-Cycle assisted desiccant air-conditioning (MDAC) system. The performance of both systems is investigated under the climatic conditions of different cities in Pakistan, representing arid and semi-arid regions. A comparative assessment is conducted based on key thermo-hygrometric parameters, including supply air temperature, relative humidity, vapor pressure deficit (VPD), dew-point effectiveness, and dehumidification potential.

Results indicate that the MDAC system exhibits superior performance due to enhanced sensible cooling and moisture control, achieving a maximum dew-point effectiveness and a dehumidification potential of up to 4.4 g/kg/h. The results also indicate that desiccant-assisted evaporative cooling systems can serve as viable low-energy alternatives to conventional VCAC systems, particularly in arid and semi-arid regions for greenhouse applications.

Keywords: Air conditioning, desiccant dehumidification, evaporative cooling, greenhouse, Pakistan

Insights into Applications of Sustainable Indirect Evaporative Cooling Systems for energy-efficient control of temperature and humidity

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Abstract:

Indirect evaporative cooling (IEC) systems have emerged as energy-efficient alternatives to conventional air-conditioning technologies, particularly in regions facing rising cooling demands and climate variability. This work presents an assessment of sustainable indirect evaporative cooling solutions, with emphasis on design configurations, hybridization strategies, and application-oriented performance. In this regard, various IEC systems are systematically reviewed to address the inherent limitations and practical applications. Moreover, the study highlights the role of heat exchanger geometry, channel arrangement, and system compactness in enhancing thermal performance, scalability, and operational flexibility. Design evolution from basic IEC units to advanced hybrid configurations is discussed, demonstrating improved temperature control, humidity management, and energy efficiency. Performance outcomes reported in recent case studies indicate that hybrid IEC systems can significantly reduce cooling energy consumption while maintaining acceptable thermal comfort across diverse climatic conditions. A wide range of practical applications is examined, including human thermal comfort in residential and commercial buildings, crop production in greenhouses, livestock shelter cooling, fresh and dried food storage, and industrial processes such as artifact preservation, tobacco curing, and rubber goods manufacturing. The applicability of compact and mobile IEC-based systems is also assessed. Overall, the findings confirm that sustainable indirect evaporative cooling systems offer a viable, adaptable, and energy-efficient cooling solution, providing valuable engineering insights for researchers, designers, and decision-makers seeking to expand their deployment across multiple sectors.

Keywords: temperature and humidity control; indirect evaporative cooling; system design and configuration; hybrid IEC–MVC; HVAC applications

Preparation of thin film composite membranes and modules for industrial flue gas separation

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Abstract

Capturing carbon dioxide (CO_2) from the atmosphere and industrial gas streams is essential to mitigate global warming and reduce environmental instability. Rising CO_2 concentrations have contributed to severe climatic changes, including floods, droughts, and extreme temperature variations, particularly in countries such as Pakistan. Effective CO_2 capture technologies are crucial for regulating atmospheric emissions and improving fuel efficiency. Over the past three decades, membrane technology has emerged as a promising approach for CO_2 separation due to its low energy consumption, operational simplicity, and cost-effectiveness. Conventional polymeric membranes face inherent limitations in selectivity and permeability, restricting their large-scale applicability. Primary goal is to develop advanced membrane systems, including mixed matrix membranes (MMMs), thin film composite (TFC) membranes, and interfacial composite membranes (ICM), based on various polymers like PES, CA etc. This research will incorporate different effective nanomaterials such as CNTs, GNPs, along with metal and covalent organic frameworks into polymer matrices to enhance mechanical strength and CO_2 separation performance. Permeation experiments will be conducted using pure gases as well as real flue gas streams on a custom-built unit to assess membrane performance and system integration feasibility. The developed prototype membrane system is expected to offer an energy-efficient and economically viable solution for greenhouse gas mitigation, contributing to long-term strategies for controlling global warming and industrial flue gas emissions.

Keywords

Covalent organic frameworks; thin film composite membranes; interfacial polymerization; decarbonization

Imidazolium Ionic Liquid Modified Cellulose Nanocrystal based Novel Desalination Membranes with Improved Antimicrobial and Antifouling Properties

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Abstract:

Membrane based-desalination technologies offer a promising solution to global freshwater scarcity. However, membrane fouling, limited permeability, and long-term stability remain critical challenges. This research aims at the modification of naturally abundant cellulose with imidazolium based ionic liquid that is well known for its hydrophilicity, anti-microbial, anti-fouling and efficient salt rejection properties. This modified novel material is blended with cellulose acetate in different weight percentages. The incorporation of cellulose nanocrystal improved the mechanical strength, high salt rejection and elevated water flux. The membranes are fabricated through phase inversion method using different compositions of synthesized material.

The characterization of synthesized materials and fabricated membranes is done through ^{1}H-NMR, FTIR, SEM and XRD. Membranes' performance is evaluated by contact angle, tensile testing, water flux and salt rejection capacity. The best membrane (Mem10) demonstrated high salt rejection (85.03% for $CaCl_2$, 82.3% for KCl, 76.1% for NaCl and 77.9% for sea water composition), significant water flux of 1627.68 L/m^2*h, minimal fouling i.e. 6% with 98.9% flux recovery and good mechanical strength (12.2% strain and 15.05 MPa stress). The membrane is hydrophilic having contact angle of 49.3° and exhibit remarkable antibacterial and antifungal properties which prevent it from biofouling and hence expand its durability. The results reveal successful synthesis of novel polymeric membrane having marvellous desalination capacity with exceptional effectiveness against microbes making clear water that will ensure a sustainable and efficient potable freshwater supply globally.

Keywords: RO Technology | Cellulose Nanocrystal | Ionic Liquid | Hydrophilicity | Anti-fouling

Upcycling Waste Polyethylene terephthalate (PET) Bottles into High-Performance Aluminum based metal organic frameworks (MOFs) for Sustainable Antibiotic Removal from Water

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Abstract:

The accumulation of plastic waste and the persistence of pharmaceutical contaminants in water represent two converging environmental crises of the 21st century. Here, we report a sustainable strategy that addresses both challenges simultaneously by upcycling post-consumer polyethylene terephthalate (PET) into an aluminium-based metal–organic framework (Al-DST) for efficient antibiotic removal. Disodium terephthalate (DST), derived directly from PET hydrolysis, served as a green linker precursor for the one-step aqueous synthesis of Al-DST under ambient conditions, eliminating toxic solvents and high-temperature processing. Comprehensive physicochemical characterization confirmed a highly crystalline and thermally stable framework incorporating PET-derived terephthalate linkers. The resulting MOF exhibited a remarkable tetracycline adsorption capacity of 355.9 mg g^{-1}, reaching equilibrium within 120 minutes, with adsorption governed by chemisorption-dominated pseudo-second-order kinetics. Isotherm and thermodynamic analyses revealed monolayer, spontaneous, and exothermic uptake driven by multisite coordination between Al^{3+} centers and tetracycline functional groups, reinforced by π–π stacking and hydrogen bonding. The Al-DST adsorbent maintained structural integrity over multiple adsorption–desorption cycles, highlighting its robustness and reusability. This work introduces a circular-economy approach that converts plastic waste into a value-added, high-performance adsorbent for antibiotic-polluted water, offering a scalable pathway toward sustainable water purification technologies.

Keywords: Polyethylene terephthalate (PET) waste, Aluminum-based metal-organic frameworks, Tetracycline removal from aqueous solutions, circular economy, Sustainable water treatment

Flexible Bimetallic MIL-88B MOFs for Tunable Transport in Pebax Mixed Matrix Membranes for CO_2/CH_4 Separation

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Abstract:

Dynamic control of gas transport pathways remains a key challenge in the design of high-performance mixed matrix membranes (MMMs). Here, we report a new class of MMMs that leverage the dynamic framework flexibility of bimetallic MIL-88B metal–organic frameworks (MOFs) to simultaneously enhance gas sorption and diffusion. Flexible FeCo- and FeNi-MIL-88B MOFs, including their amine-functionalized analogues, were incorporated into a Pebax®1657 matrix to create defect-minimized, high-loading MMMs with tunable transport properties. Unlike conventional rigid fillers, the "breathing" behavior of MIL-88B enables adsorption-induced pore expansion, creating adaptive transport pathways that preferentially facilitate CO2 diffusion while restricting CH4 transport. Bimetallic node engineering further modulates the local electronic environment, enhancing CO2 affinity without excessively increasing adsorption enthalpy, thereby maintaining favorable sorption–diffusion balance. In addition, amine functionalization introduces CO2-philic sites that promote selective sorption and suppress competitive CH4 permeation under mixed-gas conditions. The optimized Pebax/FeNi–NH2 MIL-88B membrane exhibits a CO2 permeability of 138.5 Barrer and a CO2/CH4 selectivity of 16.9 under mixed-gas conditions, corresponding to a 130% increase in permeability and a 67% enhancement in selectivity relative to pristine Pebax. This work establishes a design strategy in which framework flexibility, bimetallic node chemistry, and functional group engineering act synergistically to regulate coupled sorption–diffusion transport. These findings provide new insights into the role of dynamic MOF fillers in MMMs and offer a pathway toward next-generation high-performance membranes for natural gas upgrading and carbon capture.

Key Words:

Mixed Matrix Membranes (MMMs); Pebax®1657; MIL-88B; Amine-functionalized MOFs; CO2/CH4 separation; Gas permeation; Natural gas purification; Interfacial compatibility

Sustainable Cooling to Address Extreme Heat and Occupational Inequality: A Qualitative Study of Gendered and Socioeconomic Vulnerabilities among Textile Workers in Pakistan

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Abstract: Climate change-induced heat waves are increasing in frequency and intensity in Pakistan, posing serious occupational health risks for industrial workers where prolonged indoor exposure to heat from machinery, inadequate ventilation, and production systems exacerbate workers' vulnerability to heat stress and illnesses. This qualitative study examines lived experiences of heat stress and heat-related illness among textile factory workers through twelve in-depth case studies involving male and female laborers across different production units. The cases include power loom operators, stitching machine operators, dyeing unit helpers, cutting section workers, quality checkers, and senior factory workers, representing diverse ages, education levels, and employment positions. The study targets to explore factory laborers' lived experiences of extreme heat and heat-related illness and to examine how equality, diversity, and inclusion (EDI) shape vulnerability, coping, and access to workplace protection. Thematic analysis revealed that prolonged indoor exposure to heat generated by machinery, poor ventilation, production targets, and restrictive factory uniforms significantly increase workers' vulnerability to heat stress, heat exhaustion, and heat stroke. Cross-case analysis was conducted to compare experiences across gender, age groups, and job categories, with particular attention to EDI dimensions and power relations within factory environments. Wage dependency, fear of job loss, and unpaid sick leave compel workers to continue working despite illness, normalizing health risks within production-driven systems. Gendered analysis indicates that women workers experience disproportionate impacts due to biological factors, strict dress codes, limited access to rest and sanitation facilities, and the dual burden of factory work and unpaid domestic labor. Older women workers face heightened vulnerability and exclusion, while young and low-income male workers experience limited agency and protection. Participants recommended/suggested sustainable cooling solutions, including improved ventilation, industrial exhaust fans, air-cooling systems, and gender- and age-responsive rest areas to mitigate health risks and enhance workplace equity

Keywords: Extreme Heat, Textile workers, occupational health risks, Gender inequality, cooling

Determination of Thermophysical Properties in Refrigeration Fluids using Molecular Dynamics Simulation

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Abstract:

Refrigerants and refrigeration oils are essential components of cooling systems. Due to increase in global warming, environment friendly refrigerant and compatible refrigeration oils are constantly being introduced for refrigeration systems. Oil from the compressor often gets dissolved with refrigerant flowing through the system resulting in a refrigerant/refrigeration oil mixture. Accurate determination of pure refrigerant as well as mixture thermophysical properties is essential for designing and development of efficient refrigeration systems. Since, the availability of experimental data is scarce, and a molecular level understanding of refrigerant and refrigerant oils is also needed, molecular dynamic simulation provides a promising solution.

Molecular Dynamic simulation have been increasingly used to study various fluid systems and their properties. Literature reports use of MD simulation to also predict thermophysical properties of fluids. This article presents the preliminary results for the determination of thermophysical properties in pure R-32 refrigerant and POE refrigeration oil using MD simulation. The investigated properties mainly include specific heat capacity at constant pressure and temperature and isothermal compressibility. MD simulations are performed in the temperature range of 243.15 to 298.15 K using force field provided by Raabe et al. and OPLS. The post processing is performed using both fluctuations formula and standard thermodynamic method. The results are compared with experimental data, and standard thermodynamic method is found to be more accurate.

Keywords: Refrigerant, Refrigeration Oils, Molecular Dynamics Simulations

Isolation and Identification of Anaerobic Thermophilic Quorum Quenching Bacteria for Optimization of Anaerobic Membrane Distillation Bioreactor (An-MDBR)

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Abstract:

Membrane Separation systems are often hindered by fouling, which limits their maximum efficiency and sustainability. Fouling at its core is a biological phenomenon and remains a major operational challenge in anaerobic membrane bioreactors (An-MBRs), which employ membrane filtration to treat diverse wastewaters. In An-MBRs, bacterial communication, also known as Quorum Sensing (QS) regulates biofilm formation through production of signalling molecules; N-acyl homoserine Lactones (AHLs). The resulting biofilms comprising of microbial cells embedded in extracellular polymeric substances (EPS) and soluble microbial products (SMP) decline membrane performance. Among existing fouling mitigation strategies, biological fouling control is considered the most environmentally sustainable approach. Quorum Quenching (QQ), which disrupts QS pathways, offers a promising alternative to conventional fouling control methods. This study investigates isolation of thermophilic, anaerobic bacterial strains with potential quorum quenching ability for future application in biofouling mitigation in anaerobic Membrane Distillation Bioreactor (An-MDBR). Anaerobic Sludge was collected from a local distillery bio-reactor and subjected to six sequential enrichment cycles. Enrichments were conducted at 35°C, 45°C and 55°C using Minimal Salt medium and N-acyl homoserine Lactones (AHLs) as the sole carbon source to selectively promote thermophilic, anaerobic bacterial populations with potential Quorum Quenching activity. Both Enrichment and isolation were performed in anaerobic chamber (BACTRON300, Sheldon Manufacturing Inc., USA). A total of thirty morphologically distinct colonies were successfully isolated across three temperatures. The isolates will be screened for Quorum Quenching activity through quantitative analysis of AHL degradation using High Performance Liquid Chromatography (HPLC) and bacterial identification using 16srRNA gene sequencing. Ongoing work aims at forming a viable thermophilic QQ Consortium, which will be immobilized in polymeric beads and added to a lab scale An-MDBR system to evaluate its potential for biofouling control. The outcomes of this study are expected to contribute to the development of biologically driven fouling control strategies for thermophilic membrane separation.

Keywords: Membrane Biofouling; Quorum Quenching; 16srRNA; Membrane Bioreactor; Thermophiles

Investigating halophilic Quorum Quenching Consortium for biofouling control in Anaerobic Forward Osmosis Membrane Bioreactor (An-OMBR)

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Abstract:

Anaerobic MBRs involving anaerobic digestion holds advantage over aerobic MBRs, due to reduced footprints, limited sludge production, and added value of biogas production. In recent years, anaerobic osmotic membrane bioreactor (An-OMBR) consisting of forward osmosis (FO) membranes coupled with anaerobic digestion has shown promising results in terms of nutrients and energy recovery potential. Biofouling remains a problem, limiting the long-term operational efficiency of An-OMBRs, and impacting the membrane lifespan.

Harnessing quorum quenching (QQ) bacteria has been investigated as a potential solution. Furthermore, isolation and application of potential Halophilic QQ strains could be a better choice for An-OMBRs. It is hypothesized that the viability and performance efficiency of QQ strains tolerant to salt conditions should be better for fouling control in An-OMBRs compared to strains isolated from activated and anaerobic sludge without halophilic environment. This study aims to isolate and characterize the halophilic bacteria capable of degrading a wide range of Acyl homoserine lactones (AHLs), i.e., a root cause of membrane biofouling. A consortium of the most potent QQ strains will be developed under various saline condition and AHLs degradation ability.

Firstly, sequential enrichment was done from three saline anaerobic sludge samples, using two different media, ten signal molecules and three NaCl concentrations (2%, 5% and 10%). A total of 60 halophilic strains were isolated using medium supplemented with required salinities. The isolates are undergoing identification via 16SrRNA. The characterization of strains is being done via growth rate analysis using optical density to confirm their anaerobic or facultative nature. Additionally, strains are also being characterized for AHL detection and quantification via HPLC. On detection of quorum quenching ability, a halophilic quorum quenching consortium will be developed with strains possessing overlapping AHL degradation ability for biofouling control.

Keywords: Anaerobic Halophilic bacteria, Quorum Quenching, Biofouling control, Acyl Homoserine Lactones, Consortium Development.

A Hierarchically Porous Silica Cage Composite for Energy Efficient Air Dehumidification

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Water vapor removal from the air is critical not only for human comfort but also for the preservation of moisture-sensitive materials and the efficiency of diverse industrial and environmental applications. Effective dehumidification holds significant potential to reduce energy consumption and minimize the overall operational costs associated with process streams. The composite adsorbent SIL Cage-6-62 unlike the conventional adsorbents meets the requirements desirable for the indoor dehumidification in that it performs dual functionality for moisture control within the recommended range of relative humidity (45-65%) set by American Society of Heating Refrigerating and Air conditioning Engineers (ASHARE). Additionally, it exhibits an S-shape isotherm without hysteretic behavior, a property required for energy-efficient uptake and release of water. The composite material SIL Cage-6-62 exhibits an average water sorption enthalpy (H_{ads}) of 44 kJ mol^{-1}, which is comparable to the enthalpy of water evaporation (44 kJ mol^{-1} at 25 °C). Moreover, the material can be efficiently regenerated at low temperatures and maintains excellent structural stability, as evidenced by consistent performance over ten consecutive water vapor adsorption–desorption cycles.

Immobilization of a hydrophilic zwitterionic copolymer on PEI nanofiltration membranes for the removal of arsenic and selenium from wastewater

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Abstract

The trade-off between the membrane filtration performance and antifouling property is considered vital to enable functioning of membrane. A major challenge of fouling exists dealing with feed streams of industrial wastewater, which reduces the life span of the membranes. Herein, we propose a novel design route for enhanced membrane performance by immobilization of zwitterionic copolymer on polyetherimide (PEI) nanofiltration membranes. The successful immobilization of the copolymer was done through chemical grafting resulting in improved surface hydrophilicity. As a result, the water permeability of the modified membrane with copolymer ratio 7:3 (i.e., M-5) gave maximum pure water permeance (PWP) of 17.2± 0.12 LMH/bar. It also showed higher salt rejection giving arsenic and selenium rejections of 99.49% and 98.78%, respectively. In terms of the antifouling properties, the flux recovery ratio (FRR) values for the pure PEI membranes were 73.8% and the maximum was found to be 94.23% for 7:3 M-5 membranes. To conclude, the optimization done for the flux as well as rejections, membranes modified by 7:3 copolymer using Water+IPA (M-5) seems to be the most efficient membrane giving desired results of pure water permeability (PWP) as well as the heavy metal ions rejections. To the best of our knowledge, this is the first work reported for polytherimide membrane modified with zwitterionic copolymers for the removal of arsenic and selenium.

Keywords: Zwitterionic copolymer; Nanofiltration; Arsenic; Selenium; Polyetherimide.

Rationale design of custom-built machinery for lab-scale membrane manufacturing and module fabrication

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Abstract

Polymer membranes successfully lead separation industry at commercial scale owing to their competitive separation performance and socioeconomic aspects. Unavailability of membrane manufacturing facilities at national level compels to import membrane sheets and associated materials valuing billions of dollars for acquiring membrane separation plants to fulfill national necessities. There is serious need to develop membrane technology at national level to reduce import bill, meet national demand and startup innovative business activities.

Current research aimed at developing state-of-the-art membrane technology for indigenously manufacturing flat-sheet polymer membranes, fabricating membrane modules, installing prototype separation plants for given application and suggesting ways of implementing developed technology on commercial scale to meet national demands at low cost. Indigenously developed state-of-the-art machinery can be employed to locally manufacture membrane materials. Research objectives focused on manufacturing continuous flat-sheet polymer membranes and fabricating compact multi-envelope spiral-wound modules using indigenously designed, fabricated, installed and standardized prototype machinery. Technology demonstration on pilot-scale machinery for producing membrane and modules suggests optimized ways of designing and implementing membrane application strategies on large commercial scale.

Keywords

Pilot-scale manufacturing; custom-built machinery; flat-sheet membranes; interfacial polymerization; spiral-wound module

Modified Agarose/Chitosan Composite Membrane for Efficient Removal of Urea and Creatinine from Human Urine

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Abstract:

Accurate determination of creatinine and urea levels is crucial for the early diagnosis of renal and muscular dysfunction. In this study, a **modified agarose–chitosan–based composite membrane**, incorporated with activated carbon/organically modified silicate (M-ormosil), was synthesized for the efficient removal of urea and creatinine from human urine. The structural, thermal, and physicochemical properties of the developed membrane were characterized using SEM-EDX, TGA, FTIR, and DSC analyses. The results confirmed a **sheet-like porous membrane morphology**, successful functionalization with amino groups, and satisfactory thermal stability up to 220 °C. The effects of key operational parameters, including initial pH, contact time, and initial concentrations of urea and creatinine, were systematically evaluated in real human urine samples using **response surface methodology (RSM).** Under optimized conditions, the membrane exhibited maximum adsorption capacities of **29.2 mg g^{-1} for urea** and **21.2 mg g^{-1} for creatinine**. Adsorption equilibrium data were best described by the **Langmuir isotherm model**, with high correlation coefficients (R^2 = 0.991 for urea and 0.997 for creatinine), indicating monolayer adsorption on a homogeneous surface. Kinetic studies revealed that the adsorption process followed a **pseudo-second-order model,** supported by the lowest χ^2 values (0.122 and 0.074) and high R^2 values (0.993 and 0.992) for urea and creatinine, respectively. Furthermore, regeneration and selectivity studies demonstrated the membrane's reusability and effective performance in complex biological matrices. Overall, the developed agarose–chitosan composite membrane shows strong potential for **urinary toxin removal,** offering promising prospects for integration into **advanced dialysis membranes and point-of-care renal diagnostic systems,** thereby supporting early detection and management of nephrological disorders.

Keywords: Agarose–chitosan composite membrane; Urea removal; Creatinine adsorption; Human urine treatment; Adsorption kinetics; Dialysis applications

Sustainable Desalination via Waste-Derived Thin Film Nanocomposite Membranes with Enhanced Transport and Fouling Resistance

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Abstract:

Thin film nanocomposite (TFN) membranes offer a promising pathway to overcome the permeability–selectivity trade-off in desalination. However, their large-scale deployment remains constrained by material sustainability, filler compatibility, and long-term operational stability. Here, we report a fully circular and environmentally benign TFN membrane platform in which both the active nanofiller and the membrane support are derived from waste polyethylene terephthalate (PET) bottles. An aluminum-based metal organic framework (Al-MOF) was synthesized at room temperature using water as the sole solvent, with disodium terephthalate obtained via alkaline hydrolysis of waste PET serving as the organic linker. The same waste PET was further valorized to fabricate the membrane support through phase inversion, followed by interfacial polymerization to form the selective polyamide layer. Comprehensive physicochemical characterization confirms the successful incorporation of the MOF nanofiller and its strong interfacial compatibility with the polyamide matrix, resulting in enhanced surface hydrophilicity and structural integrity. The resulting TFN membranes exhibit a modest water permeability of up to 5.27 L m^{-2} h^{-1} bar^{-1} while maintaining competitive salt rejection, reaching 78% for NaCl and 85% for $MgSO_4$. Notably, the membranes demonstrate excellent long-term operational stability and pronounced antifouling behavior, attributed to the highly hydrophilic surface and uniform nanofiller dispersion, as evidenced by contact-angle analysis and fouling resistance tests. This study establishes a scalable and low-energy strategy for fabricating high-performance TFN membranes entirely from waste-derived resources, advancing desalination membrane technology toward circular material use, reduced environmental footprint, and sustainable water treatment.

Keywords: Thin film nanocomposite membranes; circular economy; waste PET upcycling; metal–organic frameworks; sustainable desalination

Synthesis and Characterization of Zinc-Magnesium Nanoparticles Doped on Rice Husk for The Removal of Enrofloxacin from Aqueous Samples

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ABSTRACT

Pharmaceutical wastewater is considered one of the main contributors to water pollution as it contains antibiotics, antihistamines, and various other agents. Enrofloxacin, the drug under study, is used for treating bacterial infections in cats, dogs, chickens, and cattle, with a bioavailability of 82%. After its excretion, its presence in the environment can negatively impact various animals and plants, including humans. In this study, Zn-Mg nanoparticles doped on rice husk were prepared using the co-precipitation method. The synthetic nanoparticles were characterized using SEM, EDX, FTIR, and XRD analysis. The method validation of enrofloxacin was carried out using a UV-visible spectrophotometer at 320 nm. The plot of Linearity is found to follow Beer-Lambert law with R2 = 0.99, including Precision (RSD= 0.117), LOD (5.83 ppm) and LOQ (17.66 ppm) respectively. Taguchi's experiment design removed enrofloxacin from the aqueous solutions under the batch experiments. A maximum of 61% removal efficiency was achieved at 40 RPM, 2g/100mL Dose, 10mg/L Concentration, and 20 minutes of Contact Time. Different isotherms, i.e., Langmuir, Freundlich, Temkin, Dubinin-Radushkevich, and Florry-Huggins, suggested that the adsorption process is multilayer, endothermic, and spontaneous. The Kinetic studies showed that the adsorption followed a pseudo-second-order reaction, confirming that the process followed physisorption.

Keywords: *Pharmaceutical wastewater, Enrofloxacin, Rice husk, Taguchi*

Scalable synthesis of asymmetric hemodialysis membranes to enhance performance and biocompatibility in flat sheet and hollow fiber configurations

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Hemodialysis is indispensable for patients with end-stage renal disease (ESRD). Yet, the performance of conventional polymeric membranes is restricted by protein adsorption, poor hemocompatibility, and thrombo-inflammatory responses. We hypothesized that functional modification of a cellulose acetate (CA) matrix with selected additives could overcome these limitations. By enhancing hydrophilicity, permeability, and anticoagulant behaviour, such membranes could provide improved therapeutic potential. To evaluate this, CA-based flat sheet membranes (FSMs) were fabricated through non-solvent induced phase separation and scaled into hollow fiber membranes (HFMs) by dry-wet jet spinning. Polyethyleneimine (PEI) and polyethylene glycol (PEG) were incorporated to adjust the pore structure, surface chemistry, and transport properties. Citric acid and gelatin were introduced as anticoagulant agents to assess their impact on blood compatibility. A comprehensive characterization was carried out, including SEM, FESEM, AFM, FTIR, tensile testing, porosity measurements, and contact angle analysis. Membrane performance was evaluated through pure water flux and dialysis simulations with urea, creatinine, lysozyme, and bovine serum albumin (BSA). Among the FSMs, CA-4 achieved a water flux of 54.40 Lm-2 h-1 at 2 bar, with 78% urea clearance, 31% creatinine clearance, and 94% BSA retention. Transition to a hollow fiber geometry enhanced scalability and clinical relevance. HF-2 displayed a flux of 83.34 Lm-2 h-1 at 2 bar, 66.5% urea clearance, and 90.3% protein retention. These values indicate a clinically significant balance between permeability and selectivity. Biocompatibility testing showed that citric acid-modified membranes reduced platelet adhesion and thrombus formation, while maintaining hemolysis ratios below the ASTM F-756-08 threshold of 5.5%. Gelatin-modified membranes loweredhemolysis up to 2.4% but promoted protein adsorption and platelet adhesion. This makes them more suited for regenerative applications than for dialysis. Overall, the results validate the hypothesis that the integration of PEI, PEG, citric acid, and gelatin into CA membranes enhances both physicochemical and biological performance. The scalable fabrication approach presented here provides a framework for next-generation hemodialysis membranes. These membranes improve solute clearance, minimize blood incompatibility, and support safer renal replacement therapy.

Keywords: Cellulose Acetate, Formic Acid, Citric Acid, Gelatin, Hemocompatible

Modelling of Bipolar Membrane Electrodialysis for Organic Acid Recovery

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Abstract:

Recovery of multiple organic acids from dilute, fermentation-derived aqueous streams is often constrained by complex coexisting components in the product stream and by the need to minimize chemical consumption during downstream processing. Bipolar membrane electrodialysis has recently been applied to organic acid recovery, as it enables acid recovery without generating the large amounts of waste salts common in other downstream processes. In this work, a two-dimensional steady-state model based on the electroneutral Nernst–Planck equations is employed to investigate lactate recovery and citrate rejection in a two-compartment bipolar membrane electrodialysis cell. The model solves the coupled ion transport and charge conservation equations using an electroneutral Nernst–Planck formulation in both the solution compartments and the ion exchange membrane domains, with Donnan partitioning imposed at the membrane solution interfaces. Bipolar membrane behavior is captured through water dissociation and the resulting H^+/OH^- generation, which enables in situ product acidification. The effects of alkaline operation (pH 9–10) and electric field intensity (9 V/cm) are assessed for monovalent selective membranes. Model outputs include local current density, transmembrane ionic fluxes, outlet purity, and steady-state specific energy consumption calculated as electrical power input per lactate transfer rate. The model predicts that at pH 9–10, lactate remains monovalent, whereas citrate becomes predominantly multivalent, thereby improving lactate selectivity in the presence of a monovalent selective membrane. The model captures the observed trend in outlet purity and predicts a lactate purity of ~97%, which is comparable to the literature data.

Keywords: Bipolar membrane electrodialysis, Modelling, Monovalent selective membranes, Nernst–Planck equation, Organic acid recovery.

Thymol-Based Deep Eutectic Solvents: A Synergy of Experimental and Computational Insights for Ethanol-Water Separation in Green Chemistry

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Abstract:

Deep eutectic solvents (DESs) offer sustainable alternatives to volatile organic solvents for membrane separations and cooling applications, but high viscosity and hydrophilicity limit their industrial utility. This study reports three novel thymol-based type V DESs—thymol:1-butanol (4:1), thymol:2-butanol (6:1), and thymol:butanoic acid (1:1)—engineered for low-viscosity hydrophobic separations.

DES formation was confirmed via FTIR (broadened OH stretch ~3200 cm^{-1}) and ^1H-NMR (downfield-shifted OH protons), establishing robust hydrogen-bonded networks. Physicochemical characterization revealed viscosities 10-40 mPa.s, densities <0.96 g/cm^3, pH 4-6, refractive index 1.40-1.50, and excellent hydrophobicity. TGA/DSC demonstrated thermal stability >300°C, ideal for high-temperature processes. COSMO-RS modeling predicted high ethanol selectivity (S >15), validated by liquid-liquid equilibrium data.

Advanced DFT calculations provided molecular insights: interaction energies (-6 to -10 kcal/mol); ESP mapping confirmed the dual nature of thymol (HBA with acid and HBD with alcohol); and IGMH visualized H-bond domains between components of DES.

These multifunctional DESs exhibited excellent antimicrobial activity (S. aureus, E. coli, P. aeruginosa) and manageable flammability, broadening their utility beyond separations. Their low viscosity enables efficient mass transfer across hydrophobic membranes, while thermal stability supports cooling fluid applications and high-temperature separations.

This work establishes thymol-based DESs with short-chain co-formers as next-generation solvents for ICMS-relevant technologies—hydrophobic membrane separations, thermally-stable cooling media, selective alcohol separations, and biocidal processes—combining experimental validation with computational design principles for sustainable industrial deployment.

Keywords: Deep Eutectic Solvents (DESs), Ethanol-water separation, DFT, COSMO-RS

Data-Driven Design of Hydrophobic Deep Eutectic Solvents for Membrane-Based Separation Systems

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Abstract:

This study presents an integrated computational-experimental framework for developing hydrophobic deep eutectic solvents (HDESs) as sustainable separation media for ethanol–water systems with relevance to membrane-based and hybrid separation processes. Initially, 81 reported deep eutectic solvent constituents were screened using COSMO-RS to evaluate infinite dilution activity coefficients, leading to the selection of 21 components exhibiting strong ethanol affinity. These were combined to generate 265 HDES candidates using three hydrogen-bond acceptors, benzyl alcohol, DL-menthol, and thymol, and 18 hydrogen-bond donors across multiple molar ratios. Separation performance was assessed using infinite dilution selectivity and capacity, and the top 5% of candidates were shortlisted for detailed analysis. Molecular insights derived from σ-profiles and σ-potentials revealed that acceptor polarity predominantly governs selectivity, while donor hydrophobicity controls distribution behavior, key parameters influencing membrane-assisted separations such as supported liquid membranes and membrane solvent hybrid systems. Rapid screening models based on σ-profile descriptors were developed using multiple linear regression, achieving R^2 values of 0.75 for distribution and 0.85 for selectivity. Two alcohol-based novel HDESs were synthesized and characterized by FTIR spectroscopy, confirming the formation of eutectic hydrogen-bond networks. Both systems demonstrated high ethanol extraction efficiencies of 96.4% and 98.2% at 303.15 K, validating the computational predictions. The results highlight the potential of alcohol-based HDESs as low-volatile membrane-compatible separation media and demonstrate a robust strategy for screening and designing solvents suitable for next-generation membrane separation applications.

Keywords: Hydrophobic DES, Machine Learning, DFT, COSMO-RS, Membrane systems

TiO_2 Nanotubes Based Polymeric Membranes for the Removal of Carbofuran and Chlorpyrifos Pesticides from Water

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Abstract:

Agricultural pesticide contamination of water is becoming an increasing environmental and public health issue, especially in areas where farmers engage in large-scale farming activities. Chlorpyrifos and carbofuran are the most common pesticides that are found in the surface and ground water because of their high toxicity, persistence, and leaching properties. The use of nanofiltration membranes can be an effective method of treatment used in the removal of these micropollutants in water. Polyether sulfone (PES) has proven to be effective in membrane fabrication due to its high mechanical strength, thermal stability, and chemical resistance, but it has certain limitations such as its hydrophobic nature which causes membrane fouling and poor separation performance.This study focuses on improving the performance of PES nanofiltration membranes through the incorporation of titanium dioxide nanotubes (TiO_2NTs). TiO_2NTs are synthesized using a hydrothermal method and characterized by FTIR, XRD, and SEM analyses. Mixed matrix membranes are prepared via the non-solvent induced phase inversion (NIPS) technique, followed by surface modification using polyelectrolyte multilayers to form the active separation layer. The influence of TiO_2NT addition on membrane morphology, surface properties, permeability, and fouling resistance is studied in this research.
Membrane performance is assessed for the rejection of chlorpyrifos and carbofuran under different operating conditions, including pH (5.5, 7, and 9), transmembrane pressure (6 to 20 bar), and pesticide concentrations that are representative of WHO drinking-water limits. PES membranes functionalized with titania nanotubes show improved water flux, higher pesticide rejection, and better flux recovery than pristine PES membranes. The enhanced performance is due to increased surface hydrophilicity and reduced fouling tendency.
The results demonstrate that TiO_2 nanotube-based PES nanofiltration membranes have a great potential for the effective removal of toxic pesticides from contaminated water and can contribute to enhance the quality of drinking water.

Keywords: Titanium dioxide nanotubes, Polyether sulfone membranes, Chlorpyrifos, Carbofuran, Nanofiltration

Polyelectrolyte Multilayer-Based Nanofiltration Membranes with Tunable Performance for Target Pollutants

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Abstract:

In this study, we demonstrate the preparation of polyelectrolyte multilayer (PEM)-based nanofiltration (NF) membranes with highly tunable separation performance for water treatment applications. The versatility of PEM coatings makes them promising candidates as charged separation layers in NF membranes, as they offer precise control over membrane pore size and surface chemistry, including charge density and hydrophilicity. These parameters play a critical role in membrane separation processes by influencing selectivity, permeability, and fouling resistance. Membrane selectivity can be further enhanced through an asymmetric coating strategy, in which membrane pores are initially filled with relatively open polyelectrolyte (PE) layers, followed by the deposition of a thinner and denser top separation layer. Following this approach, NF membranes were fabricated via a layer-by-layer (LbL) assembly technique using poly(allylamine hydrochloride) (PAH) as the polycation and poly(styrenesulfonate) (PSS) as the polyanion on an ultrafiltration polyethersulfone (PES) support membrane. The use of long-chain PAH/PSS resulted in an open membrane separation layer with high permeability but relatively low selectivity. To further improve membrane selectivity without compromising permeability, subsequent coating with weak polyelectrolytes (PAH/PAA) was performed, followed by chemical crosslinking with glutaraldehyde. This asymmetric PEM design produced membranes with a higher molecular weight cutoff (MWCO ~1000 Da) compared to conventional PEM-based NF membranes, while maintaining enhanced rejection performance. Membrane performance was evaluated through pure water permeability measurements, dye rejection tests using dyes of different sizes and charges, and salt rejection experiments. Membrane characterization using SEM, FTIR, and contact angle. The separation behavior of the membranes was governed by a combination of Donnan exclusion and size-exclusion mechanisms. Rejection results demonstrated that dense PAH/PAA top layers were more effective for dye and salt rejection than the initial, more open PAH/PSS layers. These findings highlight the potential of PEM-based NF membranes as efficient and tunable separation layers for advanced water treatment applications.

Keywords: polyelectrolyte multilayers, NF membranes, water purification, dyes removal, resource recovery

Electrocatalytic Performance of $NiFe_{2-x}Co_xO_4$ (*x* = 0.0, 0.2, 0.4, 0.6, and 0.8) Oxides and Their Composites for Water Splitting

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Abstract:

The global energy crisis and escalating environmental concerns have intensified the need for sustainable and eco-friendly energy technologies. Among these, green hydrogen production via electrochemical water splitting has emerged as a promising alternative to fossil fuels due to its high energy density (120 MJ/kg) and zero carbon emissions. However, the widespread adoption of this technology is hindered by the high cost and limited long-term stability of conventional electrocatalysts. Nickel ferrite ($NiFe_2O_4$) is a potential candidate for water splitting due to its favorable redox characteristics, yet its performance is often restricted by poor charge transport and structural limitations. In this study, a series of Co-substituted nickel ferrites NiFe2-*x*Co*x*O4 (*x* = 0, 0.2, 0.4, 0.6, 0.8) were synthesized using a sol-gel method. Structural and morphological characterization using X-ray diffraction confirmed the formation of a pure spinel phase with a cubic crystal structure (space group: Fd3m). Scanning electron microscopy revealed a porous morphology favorable for electrocatalysis, and energy dispersive X-ray analysis verified the uniform distribution of Ni, Fe, Co, and O elements. The catalyst NiFe1.4Co0.6O4 (*x* = 0.6) exhibited the best activity, with overpotentials of 290 mV for OER and 382 mV for HER at 50 mA·cm-2, compared to 420 mV and 451 mV for pristine NiFe2O4. To further enhance performance, a GO-based composite (GO-NFC6) was synthesized, achieving even lower overpotentials of 230 mV (OER) and 273 mV (HER). Electrochemical impedance spectroscopy revealed reduced charge-transfer resistance (1.3 Ω for OER, 5 Ω for HER) and Tafel slopes of 145 mV·dec-1 (OER) and 105 mV·dec-1 (HER), indicating faster kinetics. The composite also exhibited a high electrochemical surface area of 3.81 cm2. These results demonstrate that cobalt substitution and GO integration significantly enhance the electrochemical properties of nickel ferrites, making $GO\text{-}NFC_6$ a promising bifunctional catalyst for water splitting.

Development of nanofiltration membranes utilizing zinc oxide nanoparticles for enhanced antifouling and antibacterial properties

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Abstract:

The study demonstrates the preparation of ZnO-embedded polyelectrolyte multilayers (PEMs) based NF filtration membranes for water treatment. Membrane separation is an efficient process; however, it suffers from severe fouling issues, for this reason polyelectrolyte multilayers based thin film composite (TFC), asymmetric membranes were prepared by embedding Zinc oxide nanoparticles (ZnO-NPs). Polyether sulfone (PES) polymer is used to prepare the ultrafiltration (UF) support via non-induced inversion process (NIPS) on a non-woven polypropylene support. To prepare nanofiltration membranes, UF support is then coated with PEMs of polyelectrolytes (PAH/PSS) followed by (PAH/PAA) in a layer-by-layer assembly fashion. In the final layer of PEMs, ZnO-NPs are embedded via dip coating. The ZnO nanoparticles were nanoscale (85 nm) with high colloidal stability (zeta potential −78.5 ± 2.5 mV). Characterization using SEM–EDS, XPS, and FTIR confirmed uniform PEM formation, successful ZnO incorporation, and increased membrane hydrophilicity and surface charge. Performance tests demonstrated enhanced rejection of Congo Red and Rose Bengal (98%), PEG 1000 Da (82–89%), and $MgSO_4$ (58.5%). Fouling experiments with BSA, humic acid, and E. coli revealed up to 27% reduction in fouling and improved flux recovery for ZnO-modified membranes compared to PEM membrane-15. These results highlight that ZnO-embedded PEM NF membranes offer a robust platform combining high selectivity, antifouling, and antibacterial performance for water treatment applications.

Keywords: Polyelectrolyte multilayers, nanofiltration, non-induced phase separation, Zinc oxide nanoparticles, antifouling properties, and functional nanomaterials.

Development of Selective Mixed Matrix Membranes for Separation of Lithium Ions from Simulated Brine Solution

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Abstract
The current use of lithium as a primary source for the development of highly efficient batteries is a result of the global transition from traditional fossil fuels towards renewable energy. Natural brine resources represent a major lithium source. Membrane-based separation has emerged as a promising alternative to conventional extraction techniques due to its low energy efficiency, operational simplicity, and environmental footprint. This study focuses on the development of a selective mixed matrix membranes (MMM) for the separation of lithium ions from simulated brine solutions.

In this work, mixed matrix membranes are fabricated by incorporating lithium-selective inorganic filler material into a polymeric membrane matrix. The polymer is selected based on its mechanical and thermal stability, chemical resistance, and suitability for aqueous ionic environments, while the filler was chosen for its preferential interaction with lithium ions. The incorporation of the selective filler aimed to enhance lithium ion transport while suppressing the passage of competing ions present in brine solutions. Simulated brine solutions are prepared to evaluate membrane performance under conditions representative of natural lithium brines.

Comprehensive membrane characterization is conducted to assess structural and physicochemical properties. Morphological analysis is carried out to study uniform dispersion patterns of the filler within the polymer matrix. Key properties such as, mechanical stability, ion exchange capacity, and membrane selectivity are evaluated to ensure membrane stability during operation. The separation performance and Lithium ion transport are investigated using a laboratory-scale replaceable membrane cell, and ionic concentrations are quantified through conductivity-based calibration methods.

The results demonstrate that the developed mixed matrix membranes exhibit significantly improved lithium ion selectivity. Enhanced lithium transport is attributed to the synergistic effect between the polymer matrix and the lithium-selective filler, which provides preferential pathways for lithium ions while limiting the transport of competing cations. The membrane also showed stable performance during prolonged testing, indicating its suitability for practical brine separation applications.

The findings provide valuable insights into membrane material design and contribute to the advancement of membrane-based technologies for sustainable lithium extraction. Moreover this study highlights the potential of selective mixed matrix membranes as an effective and environmental friendly approach for lithium recovery from brine resources.

Keywords : Mixed Matrix Membrane, Lithium ions, Brine, Electro-dialysis

Zn-Co nanoferrites incorporated polysulfone nanofiltration membranes for wastewater treatment

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Abstract:
Membrane technology can also be used to overcome the rising issues related to the provision of clean environment and potable water. Polymer membranes that have been enriched with nanomaterials have wide applications in the selective extraction of the heavy metals in the polluted aqueous streams. Due to their high mesoporosity, large surface area, and strong chemical and thermal stability, nanoparticles of Zn-Co nanoferrite ($Zn_{1-x}Co_xFe_2O_4$) were incorporated into a polysulfone (PSF) to produce mixed-matrix membranes through a wet phase inversion process. $Zn_{1-x}Co_xFe_2O_4$ nanoparticles (x = 0.2, 0.4, 0.6, 1.0) with a diameter of 29-45nm were hydrothermal grown in unannealed and annealed forms and incorporated into the PSF matrix to determine the effect of annealed nanoferrite on the separation properties of the obtained membranes. Thorough characterization was done to determine the effect of nanoferrite doping on the chemical structure, morphology, mechanical integrity, wettability, and porosity of the membranes using methods like Fourier-transform infrared spectroscopy, optical microscopy, universal testing machine, goniometer, and porosity tester; therefore, the performance of the nanoferrite-filled membrane in water desalination was significantly improved as compared with that of the pure PSF membrane with the addition of nanoferrites of different compositions.

Keywords: Zn-Co nanoferrites; Annealing effect; Composite membranes; Nanofiltration; Water treatment

Carbon Capture via Thin-Film Composite Membranes Comprising Polysulfone-Coated Vertically Aligned ZIF-302 Nanoarrays

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Abstract:

Mesoporous zeolitic imidazolate frameworks ZIF-302 nanocrystals possessing high CO_2 affinity, large surface area, and improved thermal stability find huge potential for carbon capture applications in treating post-combustion flue gases. Thin film composite (TFC) membranes prepared by growing vertically aligned ZIF-302 nanoarrays (V-ZIF-302) on cellulose acetate (CA) substrate in ZnO templates are expected to render excellent carbon capture performance. CO_2 extraction efficiency of TFC membranes was further enhanced by coating selective polysulfone (PSF) layer onto ZIF-302 nanoarrays. CA/V-ZnO/V-ZIF-302/PSF TFC membranes concocted via this unique method result in the formation of direct gas transport pathways inside the membrane structure. CO_2 transfer mostly occurring via molecular-sieving openings present in ZIF-302 nanoarrays leads to high CO_2 permeability of membranes. Formation of consecutive membrane layers was corroborated via Fourier transform infrared (FTIR) spectroscopy. Vertical alignment of ZIF-302 deposited nanoarrays rendering thin layer of well-defined structure was verified by scanning electron microscopy (SEM). Gas permeation measurements performed over prepared TFC membranes indicated improved CO_2/N_2 selectivity with greater CO_2 permeance than pure polysulfone counterpart. As compared to bare PSF membrane having CO_2 permeability of 26 Barrer and CO_2/N_2 selectivity of 12, the TFC membrane comprising CA/V-ZnO/ZIF-302/PSF layers exhibited CO_2 permeability of 77 Barrer and CO_2/N_2 selectivity of 31.

Keywords: Thin film composite (TFC) membranes; ZIF-302 nanoarrays; carbon capture; layer-by-layer assembly; high permeation membranes

Improved hydrophilicity and antifouling performance of Silver embedded polyelectrolyte multilayers (Ag-PEM) based membranes

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Abstract:

The study demonstrates the improved hydrophilicity and antifouling performance of Silver embedded polyelectrolyte multilayers (Ag-PEM) based membranes for water applications. The process of membrane separation is the most efficient but suffers fouling problems, for this reason polyelectrolyte multilayers based thin film composite (TFC) asymmetric membranes were prepared embedding silver nanoparticles (Ag-Np) to impart antiseptic and antifouling properties to the membranes. Using the phase inversion process, the ultrafiltration (UF) support was prepared transforming the polymer solution from liquid to solid phase, using Polyethersulfone (PES) polymer. The PES support was coated with a combination of weak and strong polyelectrolytes (PAH/PSS) which was followed by crosslinking to boost retention without compromising permeability. The membrane was then coated with Ag-Np and immobilized to form stable Ag-Np. Performance evaluation of the membranes was carried out in terms of permeability, dye rejection and fouling tests with BSA and E.coli. The results show us that incorporation of Ag-Np in PEM membranes enhanced the hydrophilicity of membranes and increased the dye rejection up to 70% due to dense membrane structure. Ag-Np based PEM membranes were very hydrophilic in nature. The fouling tests also indicate significant resistance against the foulant and complete killing of the bacteria on the Ag-Np membranes compared to PES and PEM based membranes without Ag-NPs. The characterization of the membranes were done through FTIR, SEM and contact angle measurements.

Keywords: Polyelectrolyte multilayers, nanofiltration, silver nanoparticles, antifouling properties, hydrophilicity, functional nanomaterials.

Enhanced Wastewater Treatment Using Functionalized Graphitic Carbon Nitride ($g-C_3N_4$) Based Composite Membrane

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Abstract:

The dynamics in the water treatment industry have promoted vast interest in the creation of better filtration membranes as the need for effective wastewater treatment increases. The present work investigates the preparation and incorporation of functionalized $g-C_3N_4$ into polysulfone membranes with the objective of improving the permeability and selectivity of the membranes, prior to fouling. In this research, the $g-C_3N_4$ was prepared by the thermal condensation of melamine. The synthesised composite membranes with different functionalized $g-C_3N_4$ loading demonstrated higher water permeability and selectivity. This work highlights that functionalized $g-C_3N_4$ can promote the development of the membrane technique to provide a strategy for water purification based on sustainability. Further studies are in progress recommended for optimizing the loading capacity of functionalized $g-C_3N_4$ for evaluating the stability of composite membrane and biofouling tendency under diverse conditions of operation.

Keywords: Wastewater treatment, composite membranes, polysulfone, functionalized $g-C_3N_4$,

Open Investigation of Metal Phthalocyanines (Co, Ni, Cu) as Efficient Electrocatalysts for Nitrate Reduction to Ammonia

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Abstract:

The typical energy intensive Haber-Bosch (HB) process, introduced in 1909, raised the importance of ammonia, from being just a pungent gas to a valuable product in the chemical industry. The reason for its large-scale ammonia production can be attributed to the utilization of cheap and readily available precursors, catalysts and conditions. On the other hand, HB process is one of the largest contributors to the gas emissions by industries, leading to pollution and global warming. To get around this obstacle, alternative methods to produce ammonia are being tried and tested at a rapid pace, including electrocatalysis (electrochemical nitrate reduction). Among the various reported electrocatalysts, metal phthalocyanines show promising results as efficient electrocatalysts due to their stable molecular structure and tight binding of metal ion. For a fair comparison of their electrochemical activities, copper, cobalt and nickel phthalocyanines were prepared in their crystalline molecular solid state via the solvothermal method. A combination of spectroscopic, microscopic and structure elucidation techniques were employed for structural characterization. Various electroanalytical techniques were used to check the electrocatalytic activities, including LSV, CV, EIS and chronoamperometry, following up with appropriate quantification methods to determine the amount of ammonia formed. Results show that copper phthalocyanine (CuPc) exhibits exceptional electrocatalytic performance, with a faradaic efficiency of 86.4 ± 3.9 % and a yield rate of 6.48 ± 0.2 $mghr^{-1}mg^{-1}$. The results suggest that the type of metal incorporated into the phthalocyanine determines the electrocatalytic activity towards nitrate reduction. CuPc shows effective binding with the nitrate ion, leading to higher ammonia production and suppression of side products.

Keywords: Electrocatalysis, nitrate reduction, green ammonia synthesis.

Seasonal Dynamics of $PM_{2.5}$ and Associated Non-Carcinogenic Health Risks for Adults and Children

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Abstract:

PM2.5, or particulate matter with a diameter of 2.5 µm or less, is capable of penetrating deep into the respiratory system and entering the bloodstream, leading to serious health effects. In this study, a low-cost sampler is used to collect 24-hour PM2.5 samples biweekly from mid-September 2025 to mid- March 2026. Polytetrafluoroethylene (PTFE) membrane filters were employed for PM2.5 sampling due to their chemical inertness and low elemental background. PTFE filters were evaluated against Glass Fiber Filters and Quartz filters to determine the most suitable membrane for trace metal study of PM2.5. The non-carcinogenic risks associated with PM2.5 exposure were evaluated using the United States Environmental Protection Agency (US EPA) health risk assessment framework, calculating Hazard Quotients (HQs) for adults and children. Gravimetric analysis showed that $PM_{2.5}$ concentrations consistently exceeded the Punjab Environmental Quality Standards (PEQS) annual limit of 15 µg/m³, peaking in November (207.6 µg/m³) and reaching their lowest in mid- to late September (90.4 µg/m³). Correspondingly, HQ values exceeded the safety threshold (HQ = 1) in all months, indicating substantial non-carcinogenic health risks for both adults and children, with the highest exposure observed in November (HQ(Adult) = 13.84, and HQ(Child) = 13.9) and the lowest in mid-September (HQ(Adult) = 6.03; HQ(Child) = 6.04). During this period, average temperatures declined from 31°C in September to about 19°C in November, and relative humidity initially decreased slightly from 64% in September to 58% in November before rising in the later months. Statistical analysis revealed a moderate negative correlation between PM2.5 and temperature (r = -0.46), indicating higher PM2.5 levels at lower temperatures and a moderate negative correlation with relative humidity (r = -0.48), suggesting that increased humidity was associated with lower PM2.5 concentrations during the study period.

Keywords: Air pollution, Particulate matter, PTFE membrane filters, Health risk assessment, Seasonal variation

Toward Green Chemistry in Membrane Science: DL-Menthol-Based DES for Hexane-Free TFC Membrane Fabrication and Water Purification

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Abstract:

Thin film composite (TFC) membranes dominate modern desalination and advanced separations, yet their interfacial polymerization (IP) fabrication still relies heavily on volatile, hazardous solvents such as hexane, creating a critical barrier to truly sustainable membrane manufacturing. Here, we introduce a transformative solvent platform strategy that enables hexane-free TFC membrane fabrication using a biodegradable deep eutectic solvent (DES) based on DL-menthol and lauric acid. Unlike conventional hydrocarbon solvents that serve only as passive carriers, molecular-level screening confirmed that this DES establishes substantially stronger interaction with trimesoyl chloride (TMC) (−19.8 kcal/mol) compared to hexane (−6.4 kcal/mol), enabling enhanced monomer compatibility, improved interfacial stability, and a new route for precision control of polyamide (PA) layer formation. Through systematic optimization of key IP parameters, we achieved TFC membranes delivering pure water flux up to 45 $L·m^{-2}·h^{-1}·bar^{-1}$ and NaCl rejection up to 88%. These results demonstrate outstanding capability for nanofiltration driven desalination. Importantly, acetone rinsing emerged as a critical post-treatment step to yield improved flux recovery, and enhanced antifouling behavior. This work establishes deep eutectic solvents as a new enabling class of IP media, shifting sustainable membrane fabrication from incremental solvent substitution to a tunable manufacturing platform. By merging green chemistry compliance with high-performance separations, the proposed approach represents a major step toward industry-ready, hexane-free TFC membranes for future desalination and water reuse infrastructure.

Keywords: Thin film composite membranes, Deep eutectic solvent, Hexane, Desalination, Computation screening

Sodium Vanadate as Cathode Material for Aqueous Zinc-ion Batteries

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Abstract:

The intrinsic intermittency and unpredictable output of sustainable energy system highlight the engineering of high-performance electrochemical energy storage systems. Though lithium-ion batteries are dominant in the current applications, their cost and safety restrictions do not permit large-scale applications. As alternatives to Li-ion systems, aqueous zinc-ion batteries (AZIBs) are relied on Zn metal and aqueous electrolytes, which are less expensive and safer by nature. The cathodes based on vanadium are of special interest due to the multielectron V^{5+}/V^{3+} redox reaction and flexible structures which allow the storage of a great deal of charge. For the low cost and high theoretical capacity, $Na_5V_{12}O_{32}$ has been reported as cathode material, but low electronic conductivity and inadequate structural robustness has limited its use. In this work, Zn-doped $Na_5V_{12}O_{32}$ (ZNVO) is synthesized to enhance electronic-ionic transport and stabilize the host lattice. The resulting material exhibits a high reversible capacity of 323 mAh/g at 0.1 A/g and retains 96% after 100 cycles and 78% after 500 cycles at 0.5 A/g. Kinetic analysis and diffusion studies reveal that the improved performance originates from balanced capacitive contributions, rapid Zn^{2+} diffusion, and robust structural integrity.

Desalination of Sea Water using Graphene and bio-composite PVC membranes by immersion method

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ABSTRACT

The escalating global water scarcity crisis necessitates the development of more efficient desalination technologies. This study focuses on the evaluation of innovative membrane materials for desalination applications, specifically membranes synthesized from Polyvinyl Chloride (PVC) integrated with bio-composites of graphene and pomegranate peel charcoal powder. Two distinct membrane compositions were investigated: a 1:1 ratio and a 1:0.5 ratio of graphene and pomegranate peel charcoal powder. These membranes were subjected to immersion in both standardized NaCl solutions and seawater samples collected from various international locations to assess their salt absorption capabilities. The structural and chemical characteristics of the membranes were thoroughly analyzed using Fourier-transform infrared spectroscopy (FTIR), energy-dispersive X-ray spectroscopy (EDX), scanning electron microscopy (SEM), and universal testing machine (UTM) assessments. The results indicate that both types of membranes demonstrate a notable ability to adsorb salt, with pH change from 9.3 to 5.6 with variations in efficiency based on the composition ratio and the type of sea water sample from (Australia, KSA, and Pakistan) tested.

Key words: PVC, Desalination, bio-composites, graphene, and polymer

Development of Alternate Perfluoro Membranes for the Safe Transportation of Hydrogen Peroxide

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Membranes for hydrogen peroxide transport require very high strength and stability. The membranes should exhibit sufficient vapor permeability while preventing liquid H2O2 and maintain long term structural integrity and chemical stability under highly oxidative environment. In this study, flat sheet polyvinylidene fluoride (PVDF) membranes were fabricated via non-solvent induced phase inversion (NIPS) method using dimethylacetamide (DMAc) and dimethylformamide (DMF) as casting solvents, with polymer concentrations ranging from 10 to 20 wt %. By systematically varying solvent system and polymer concentrations, the influence on morphology, transport and stability was examined and compared with commercial polytetrafluoroethylene (PTFE) membranes. Pure water flux measurements showed dependence on polymer concentration, resulting in decreased permeance as membrane density increased. Lower PVDF concentrations produced more open pore structures and higher flux, while increasing polymer concentration exhibited controlled resistance to transport. Hydrogen peroxide transport exhibited a pronounced phase dependent response. Liquid phase flux decreased substantially relative to water, reflecting higher density, viscosity, and restricted pore accessibility. In contrast, hydrogen peroxide vapor transport remained high across all PVDF membranes, indicating that diffusion through the porous matrix governs vapor phase transport.Among all concentrations, the 17 wt % PVDF membrane cast from DMAc showed the most balanced results and suitable performance. This membrane exhibited moderate water permeance with high liquid entry pressure, effectively restraining liquid penetration while sustaining high vapor permeability. Vapor flux values exceeding 1800 GPU were achieved and were comparable to, and in some cases higher than, those of PTFE, despite the lower intrinsic hydrophobicity of PVDF. The reduced liquid phase flux observed for this formulation further highlighted the role of controlled structural resistance in enhancing functional selectivity. Scanning electron microscopy (SEM) revealed that the superior performance of the 17 wt % PVDF/DMAc membrane was a result of well-developed asymmetric structure with interconnected pores and limited macrovoid formation. DMF based membranes, while more uniform, did not achieve the same balance between permeability and liquid resistance. Thermal stability was confirmed by thermogravimetric analysis, with all PVDF membranes maintaining integrity well beyond operational temperatures. Differential scanning calorimetry indicated preserved crystalline behavior across formulations. Long term immersion testing in concentrated hydrogen peroxide showed no visible degradation, confirming sustained chemical stability under oxidative conditions. Hence, the developed PVDF membranes serve as a viable and controllable alternative to PTFE for advanced oxidative separation applications.

Enhanced Degradation of Ranitidine Using PVDF@$CoFe_2O_4$ Catalytic Membrane: Optimization of Co:Fe Ratio

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Abstract:

Water pollution is a major global concern, and membrane technology can be considered as the possible solution. In this research, $CoFe_2O_4$ nanoparticles with varying Co:Fe molar ratios (2:1, 1:2, 3:1, and 4:1) were prepared via hydrothermal method and fabricated into polyvinylidene fluoride (PVDF) membranes using the nonsolvent-induced phase separation (NIPS) process. Among these, the PVDF@$CoFe_2O_4$ membrane with a Co:Fe ratio of 4:1 exhibited the highest catalytic activity, achieving 99.9% degradation of the probe pollutant ranitidine upon activation of peroxymonosulfate (PMS). The superior performance of the 4:1 ratio might be due to the optimal loading of cobalt content, which provides a higher density of active sites for PMS activation, facilitating enhanced generation of sulphate radicals ($SO_4^{-\bullet}$) and hydroxyl radicals ($OH^{\bullet}$), the key reactive oxygen species, responsible for pollutant degradation. These findings demonstrate the potential of the PVDF@$CoFe_2O_4$ catalytic membrane for efficient removal of organic contaminants in water treatment applications.

Keywords: Hydrothermal, Peroxymonosulfate, Contaminants

Nanoconfined Catalytic Membranes for Emerging Pharmaceutical Contaminants (PCs) Degradation

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ABSTRACT

The increasing release of pharmaceutical contaminants into aquatic environments has raised serious concerns regarding water quality and public health. Conventional wastewater treatment processes are often ineffective in completely eliminating these emerging pollutants. Advanced oxidation processes (AOPs) show high degradation efficiency; however, their practical application is limited by catalyst recovery, stability, and energy consumption. Membrane-based catalytic systems offer a sustainable alternative by integrating separation and degradation into a single platform. In this work, a novel **PVDF-based nanoconfined catalytic membran**e is fabricated for the degradation of **ranitidine** using **peroxymonosulfate as an oxidant.** Composite membranes with varying catalyst loadings and different metal-to-metal ratios are prepared to optimize catalytic performance. The structural and morphological characterization revealed the uniform dispersion of particles within the PVDF matrix, ensuring effective nanoconfinement and minimal pore blockage.

The nanoconfined environment facilitates the efficient activation of PMS, generating reactive oxygen species (ROS) that are responsible for the degradation of pharmaceutical contaminants (PCs), such as ranitidine. The catalytic oxidation within these membranes demonstrates a significant enhancement in ranitidine removal compared to the pristine PVDF membrane. The influence of catalyst loading and metal ratio uncovers the optimized compositions for superior degradation efficiency while maintaining acceptable membrane permeability. Ranitidine is transformed into **less toxic byproducts**, being detoxified. The improved performance is attributed to enhanced electron transfer, increased active sites, and confined reaction pathways within membrane pores. Compared to conventional powder catalysts, the membrane system offered better stability, reusability, and continuous operation. The idea is to fabricate a novel nanoconfined membrane as a promising candidate for sustainable wastewater treatment and further degradation of **ciprofloxacin, nano/microplastics,** with evaluation of performance under varying conditions.

Scalable synthesis of PET-derived mixed matrix membranes for enhanced carbon dioxide separation

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ABSTRACT

The separation of carbon dioxide (CO2) from natural gas streams will play a vital role in reducing greenhouse gas emissions and improving the quality of clean energy. Conventional gas separation technologies, such as chemical absorption and cryogenic distillation, are highly energy-intensive, which motivates the development of more efficient alternatives. Membrane-based separation offers significant advantages; however, its performance is often restricted by the inherent trade-off between permeability and selectivity in polymeric membranes. This proposed research will address these limitations through the development of mixed matrix membranes (MMMs) based on Pebax 1657 incorporated with bimetallic UiO-66 metal organic frameworks (MOFs).

In this study, PET-derived bimetallic UiO-66 MOFs will be synthesized. The MOFs will be further functionalized with amine groups to improve the CO2 adsorption capacity in the mixed-matrix membranes. A series of MMMs both freestanding and composite membranes with different MOF loadings will be prepared to study the influence of filler content and surface chemistry on membrane morphology and separation behavior. The membranes will be characterized using FTIR, XRD, and SEM/EDS to examine chemical interactions, crystalline structure, and the distribution of MOF particles within the polymer matrix.

Gas permeation tests with pure and mixed gases will be performed under controlled operating conditions to evaluate permeability, selectivity, and membrane stability. The bimetallic UiO-66 MOFs, owing to their high surface area, tunable pore structure, and strong CO2 affinity, are expected to enhance gas transport and polymer filler compatibility. The outcomes of this work will provide important insight into the design of high-performance Pebax-based MMMs and support the development of energy-efficient and scalable membrane technologies for natural gas purification and CO2 separation

Environmental friendly membrane for efficient removal of microplastics

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Abstract:

The removal of nano- and microplastics from aquatic systems remains challenging due to wide variations in particle size and surface chemistry, while conventional membranes are fundamentally limited by pore-size constraints that compromise either selectivity or permeability.

Here, we report a charge-selective, high-flux membrane with an oriented active architecture that enables interaction-driven capture beyond conventional size exclusion. This design preserves interconnected porosity while maximizing exposure of functional sites to flow, achieving a water flux of 6653 L m^{-2} h^{-1} and a permeability of 9.94 × 10^3 L m^{-2} h^{-1} bar^{-1}.

The membrane demonstrates >95% removal of diverse plastics (PS, HDPE, PET, PVDF) across 500 nm to 50 µm, and >90% removal at 100 nm, with stable performance over 50 cycles. In complex matrices, simultaneous removal of multiple contaminants is achieved, including PVDF (99%), dyes (100%), pharmaceuticals (93%), and perfluoroalkyl substances (PFAS), including PFDA (88%).

A circular end-of-life pathway is further demonstrated by converting spent membranes into functional energy storage materials, delivering a capacitance of 651.5 F g^{-1}.

This work establishes a scalable strategy for active membrane architectures that integrate high-performance separation with circular resource recovery, advancing next-generation water treatment technologies.

Keywords: Microplastics, Membrane filtration, PFAS, High-flux membranes, Circular economy

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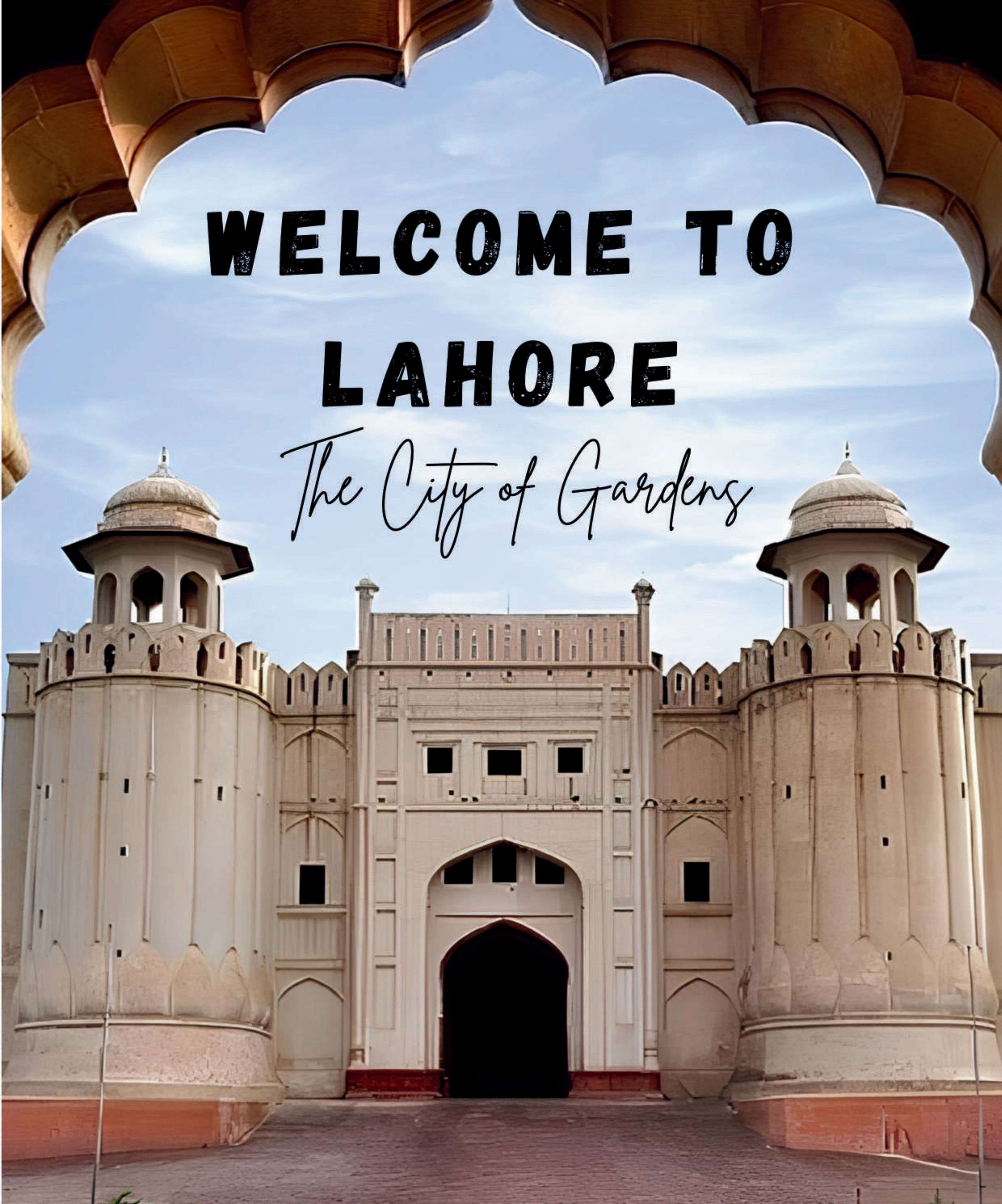
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