IITB-Monash Research Academy

An Indian-Australian research partnership

Indian Institute of Technology Bombay | MONASH University

Project Title:	Nanomaterial Supported on Cellulose Nanofibers Photocatalytic Membrane Process Integrated with Membrane Bioreactor for Emerging Contaminant Removal from Municipal Wastewater	
Project Number	**IMURA1287**	
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Research Clusters: **Research Themes:**

Highlight which of the Academy's CLUSTERS this project will address? *(Please nominate JUST **one.** For more information, see www.iitbmonash.org)*		**Highlight which of the Academy's Theme(s) this project will address?** *(Feel free to nominate more than one. For more information, see www.iitbmonash.org)*	
1	*Material Science/Engineering (including Nano, Metallurgy)*	***1***	*Artificial Intelligence and Advanced Computational Modelling*
2	*Energy, Green Chem, Chemistry, Catalysis, Reaction Eng*	2	*Circular Economy*
3	*Math, CFD, Modelling, Manufacturing*	3	*Clean Energy*
4	*CSE, IT, Optimisation, Data, Sensors, Systems, Signal Processing, Control*	4	*Health Sciences*
5	*Earth Sciences and Civil Engineering (Geo, Water, Climate)*	5	*Smart Materials*
6	*Bio, Stem Cells, Bio Chem, Pharma, Food*	6	*Sustainable Societies*
7	*Semi-Conductors, Optics, Photonics, Networks, Telecomm, Power Eng*	7	*Infrastructure*
8	*HSS, Design, Management*		

The research problem

Define the problem

The treatment of municipal wastewater has become a critical environmental challenge due to the increasing presence of emerging contaminants, including pharmaceuticals, personal care products, pesticides, and endocrine-disrupting compounds. These pollutants, often found at trace levels, pose significant risks to aquatic ecosystems and human health. Conventional wastewater treatment plants are not specifically designed to remove such contaminants effectively, necessitating the development of advanced treatment technologies (Tran et al., 2021; Mirajkar et al., 2022). Among these pollutants, antibiotic residues and antibiotic-resistant bacteria (ARB) have become a growing concern due to their potential to facilitate the spread of antimicrobial resistance (AMR) in aquatic environments. The proliferation of ARB in wastewater treatment systems poses a serious threat to human health by reducing the effectiveness of antibiotics, which are critical for treating bacterial infections. Membrane bioreactors (MBRs) have gained significant attention due to their superior filtration and biodegradation capabilities, offering improved effluent quality compared to conventional activated sludge processes. However, MBR systems face significant operational challenges, including membrane fouling, high energy consumption, and biofilm formation, which limit their long-term sustainability and efficiency (Wang et al., 2020; Zhang et al., 2021). To address these challenges, researchers have explored the incorporation of photocatalytic nanomaterials into membrane structures to enhance pollutant degradation and mitigate fouling.

Zinc oxide (ZnO) is a promising photocatalytic material with excellent antibacterial properties, high photocatalytic efficiency, and cost-effectiveness. Its ability to generate reactive oxygen species (ROS) under UV and visible light irradiation makes it a strong candidate for the degradation of organic pollutants (Rahimi et al., 2018). However, challenges associated with ZnO include nanoparticle aggregation, limited stability in aqueous environments, and potential leaching, which may reduce its effectiveness. To overcome these limitations, cellulose nanofibers (CNFs) have been proposed as a robust support material for ZnO nanoparticles. CNFs are derived from renewable biomass sources, exhibit high surface area, mechanical strength, and hydrophilicity, and can enhance the dispersion and stability of ZnO within membrane structures (Mohammed et al., 2020; Singh et al., 2023). The integration of ZnO-supported CNF membranes into MBR systems holds great potential for improving the removal efficiency of emerging contaminants while simultaneously reducing membrane fouling and enhancing antimicrobial resistance. Despite these advantages, several challenges remain in developing and implementing ZnO/CNF photocatalytic membranes in MBR systems. Key challenges include optimizing the synthesis process for uniform ZnO nanoparticle distribution, ensuring long-term stability under operational conditions, assessing potential

toxicity impacts of ZnO leaching, and scaling up the technology for industrial applications. Addressing these issues requires a multidisciplinary approach, incorporating materials science, environmental engineering, and microbiology to develop an efficient and sustainable membrane-based wastewater treatment system. This research will focus on synthesizing and characterizing ZnO/CNF membranes, evaluating their photocatalytic degradation efficiency for emerging contaminants, integrating them into an MBR system, and analyzing their antifouling and microbial resistance properties. The outcomes will contribute to the advancement of sustainable wastewater treatment technologies with enhanced efficiency and longevity.

References

Tran, T. et al. (2021). Recent advances in membrane technology for wastewater treatment. Journal of Membrane Science, 620, 118942.
Mirajkar, S. et al. (2022). Photocatalytic membrane reactors for emerging contaminant removal. Water Research, 210, 118007.
Wang, X. et al. (2020). Antifouling strategies in MBRs: A review. Bioresource Technology, 314, 123728.
Rahimi, M. et al. (2018). ZnO-based photocatalytic membranes for water purification. Environmental Science & Technology, 52(14), 8574-8585.
Mohammed, S. et al. (2020). Cellulose nanofiber composites for membrane applications. Carbohydrate Polymers, 230, 115636.
Singh, R. et al. (2023). Sustainable nanocomposite membranes for water treatment. Chemical Engineering Journal, 451, 138674.

Project aims

Define the aims of the project

- Fabrication and characterization of ZnO-supported cellulose nanofiber membranes with optimized photocatalytic properties.
- Optimize the efficiency of ZnO-supported cellulose nanofiber membranes using different light sources
- To evaluate the photocatalytic degradation efficiency of ZnO/CNF membranes for emerging contaminants in municipal wastewater.
- To integrate the developed membranes with an MBR system and assess their performance in terms of contaminant removal, antifouling properties, and microbial resistance.

How skills/experience of the IITB and the Monash supervisor(s) support the proposed project

IIT Bombay: Prof. Singh has experience on running hybrid membrane and MBR systems so all the experiments will be done at IITB for the emerging contamination (pharmaceutical) removal.
Monash: The Monash supervisor is an expert in membrane fabrication, so the membrane will be fabricated at Monash.

What is expected of the student when at IITB and when at Monash?

Highlight how the project will gain from the students stay at IITB and at Monash

IITB: The Student will perform the integrated system performance at IITB

Test the MBR-Membrane system with multiple wastewater samples.

Analyse water flux, contaminant removal efficiency, and membrane fouling behavior.

Microbial community analysis to assess antimicrobial properties and the reduction of antibiotic-resistant bacteria and genes.

Monash: The student will fabricate the membrane and characterize it.

Expected outcomes

Highlight the expected outcomes of the project

- Enhanced Removal of Emerging Contaminants.
- Reduction of Antibiotic-Resistant Bacteria and Genes
- Energy-Efficient and Cost-Effective Wastewater Treatment
- Feasibility for Large-Scale Applications:

How will the project address the Goals of the above Themes?

Describe how the project will address the goals of one or more of the 6 Themes listed above.

Out of 7 Themes 4 are directly related to our proposed project.

Circular Economy: water recycling

Health Sciences: Treated water decreases the health effect and control of antibiotic-resistant bacteria

Smart Materials: Use of advanced generation membranes

Sustainable Societies: Directly relates to wastewater treatment,

How well the IITB and the Monash supervisor(s) know each other

Provide details of previous collaborations (if any). For new collaborators, have you had a chance to meet each other in person or through VC or Skype?

IITB Supervisor visited Monash in Nov 2024 and interacted with him about the potential collaboration

Potential RPCs from IITB and Monash

Provide names of the potential research progress committee members (RPCs) and describe why they are most suited for the proposed project

IIT Bombay: Prof. Amritanshu Shriwastav (Wastewater treatment), Prof. Indrajit Chakraborty (Biological process)
Monash:
Professor Huanting Wang; Prof. Matthew R Hill

Capabilities and Degrees Required

List the ideal set of capabilities that a student should have for this project. Feel free to be as specific or as general as you like. These capabilities will be input into the online application form and students who opt for this project will be required to show that they can demonstrate these capabilities.

Master's in Environmental or chemical engineering, have basic skills in experiments

Necessary Courses

Name three tentative courses relevant to the project that the student should complete during his/her coursework at IITB (the student will require to secure 8 point in these courses)

Membrane processes
Wastewater treatment
Environmental Chemistry
Environmental Microbiology

Potential Collaborators

Please visit the IITB website www.iitb.ac.in OR Monash Website www.monash.edu to highlight some potential collaborators that would be best suited for the area of research you are intending to float.

K**eywords** relating to this project to make it easier for the students to apply.

Wastewater, emerging contaminants, membrane bioreactor, antimicrobial-resistant bacteria