Machine Learning-Driven Identification of Polymer Accumulation Hotspots and Targeted Intervention Strategies in Tropical River Systems

Fatin Nuranisha Mohd Abdul Gani[1], Mohamad Danial Shafiq[2], Hiroshi Uyama[3], Mohd Sukri Bin Shafie[4], Mohd Saiful Samsudin[1]

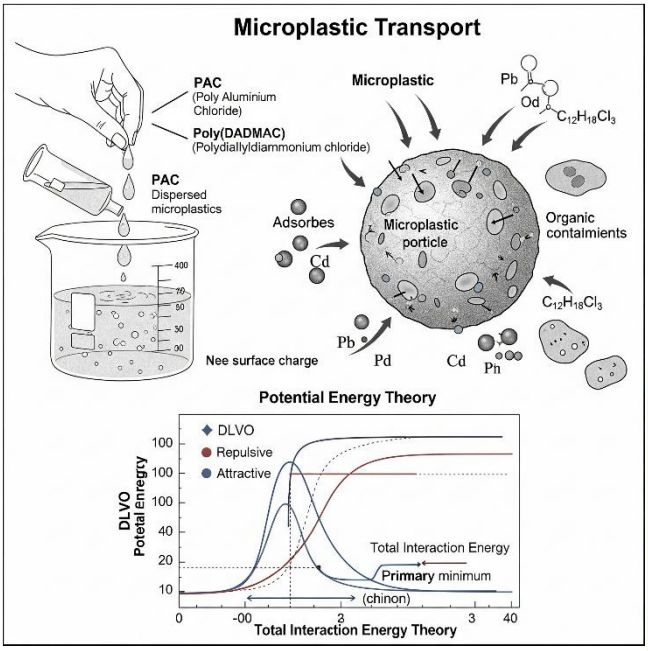
e-mail: saifulsamsudin@usm.my

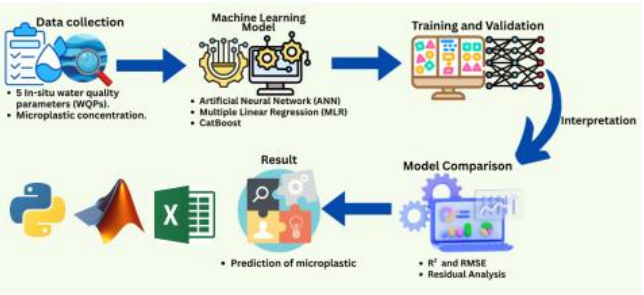
[1]*School of Industrial Technology, Universiti Sains Malaysia (USM), 11800 Pulau Pinang, Malaysia*
[2]*School of Materials and Mineral Resources Engineering, Universiti Sains Malaysia, Engineering Campus, 14300, Penang, Malaysia*
[3]*Department Of Applied Chemistry, Graduate School of Engineering, Osaka University, Japan)*
[4]*Centre for Global Sustainability Studies (CGSS), USM, 11800 Pulau Pinang, Malaysia*

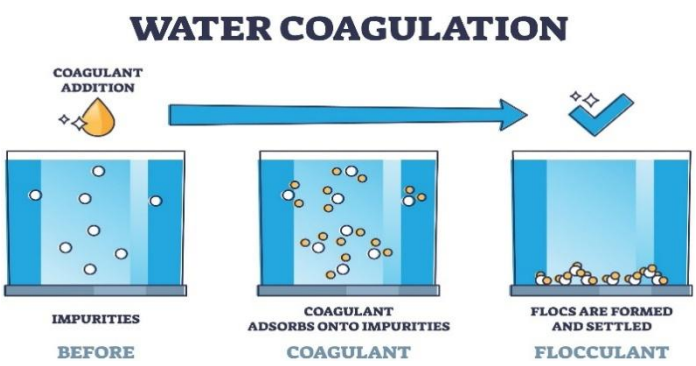
Abstract

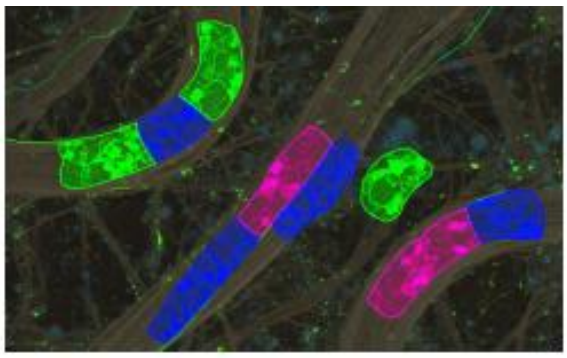
Polymer-based microplastic particles in freshwater systems represent a critical challenge for sustainable material management, particularly in tropical urban rivers characterised by complex hydrodynamics and diverse anthropogenic inputs. While existing studies predominantly focus on abundance and morphological classification, limited attention has been given to understanding how polymer properties govern spatial accumulation and how this knowledge can be translated into targeted intervention strategies. This study presents a data-driven framework integrating spatial hotspot analysis and machine learning to identify polymer accumulation zones in Pinang River, Malaysia. Field-based characterisation revealed the dominance of fibrous and fragmented polymers, primarily polyethylene and polypropylene, with distinct hotspot formation associated with urban discharge points and hydrological variability. Spatial statistical analysis was applied to identify significant clustering patterns, representing key polymer leakage pathways within the river system. To enhance predictive capability, machine learning models were developed using physicochemical water quality parameters and spatial attributes to estimate microplastic distribution and hotspot probability. To further interpret these system-level observations, mechanistic and coagulation studies were conducted to evaluate particle behaviour and removal efficiency using polyaluminium chloride (PAC) and polydiallyldimethylammonium chloride (PolyDADMAC). The results indicate that polymer properties, including morphology and aggregation behaviour, play a critical role in governing both environmental distribution and treatment performance. The integration of hotspot identification, predictive modelling, and treatment evaluation provides a framework for targeted intervention, enabling more efficient resource utilisation and supporting circular wastewater management strategies. This framework contributes to ongoing international efforts in plastic resource circulation and sustainable water management under collaborative research initiatives.

Scheme I









References 1) Gao, L., Su, Y., Mehmood, T., Wang, Z., Peng, L., & Zhang, N. UVA-induced weathering of microplastics in seawater: surface property transformations and kinetics. Frontiers in Marine Science, 12. https://doi.org/10.3389/fmars.2025.1519668. (2025). 2) Rosli, M. I. F. M., Samsudin, M. S., Yamen, S. N., Norizan, M. N., & Azid, A. (2025). Understanding the Extent of microplastic pollution in Penang's River: A baseline study on abundance and distribution of microplastic and water quality parameters. Malaysian Journal of Fundamental and Applied Sciences, 21(4), 2244–2255. https://doi.org/10.11113/mjfas.v21n4.3625. (2025) 3) Ibrahim, N., Rahman, A. M. N. A. A., Shafiq, M. D., Lockman, Z., Jaafar, M., & Kameda, Y. Microplastic pollution: sources, degradation mechanisms, analytical advances, and mitigation strategies for environmental sustainability. Reviews of Environmental Contamination and Toxicology, 263(1), 1-42. (2025)

Biography (For Plenary, Keynote, and Invited Speakers)

Name: Mohd Saiful bin Samsudin

Title: **Dr.**

Affiliation: **School of Industrial Technology, Universiti Sains Malaysia**

Country: **Malaysia**

Phone: **+60176141206**

E-mail: **saifulsamsudin@usm.my**

Personal History:
Dr. Mohd Saiful Samsudin is a Senior Lecturer at the School of Industrial Technology, Universiti Sains Malaysia (USM), specialising in environmental data analytics, microplastic pollution, and water system modelling. His research focuses on understanding the transport dynamics, spatial distribution, and environmental behaviour of polymer-based microplastics in tropical river systems, integrating machine learning, chemometric approaches and spatial analysis. He currently serves as Principal Investigator for multiple research grants, including the USM Short-Term Matching Research Grant 2025 in collaboration with The University of Osaka under the JSPS Core-to-Core program. His research emphasises the development of data-driven environmental intelligence frameworks and predictive decision-support systems to enhance water quality management and support circular resource strategies. Dr. Saiful has actively contributed to interdisciplinary research combining environmental analysis and modelling with applications in microplastic transport, wastewater treatment optimisation, and environmental monitoring systems. His work aims to bridge the gap between system-level environmental understanding and practical engineering solutions, particularly in addressing emerging pollutants in tropical environments. He has published in reputable international journals and continues to collaborate with international partners to advance sustainable water management and plastic resource circulation. His current research direction focuses on integrating machine learning and spatial analysis to identify critical intervention points in river systems, supporting efficient and targeted strategies for circular wastewater management**.**

Research Keyword (3-5 keywords use commas to separate each word):
Microplastics, Polymer Behaviour, Machine Learning, Hotspot Analysis, Circular Water Management