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MICROPLASTIC CONTAMINATION IN URBAN COASTAL WATER OF JOHOR STRAIT: EVIDENCE FROM PENDAS, JOHOR BAHRU

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Abstract — This study assessed microplastic contamination in surface water and sediments from Pendas, Johor Bahru, along the Johor Strait, between March and August 2025. Microplastics were extracted using hydrogen peroxide digestion and density separation, then identified under a stereomicroscope, with selected particles confirmed by Raman spectroscopy. A total of 101 particles were recorded, comprising 86 in water and 15 in sediment, indicating that the Johor Strait functions as a receptor of anthropogenic plastic waste. Fibres dominated (71%), followed by fragments (29%), with no films, beads or foams detected. Raman analysis confirmed polyethylene (PE) and polypropylene (PP) as major polymers, reflecting sources from fishing gear, nets and consumer packaging. Blue (47%) and black (30%) particles were most common, suggesting inputs from textiles, fishing activities and port operations, while transparent, red and brown particles were linked to single-use plastics and aquaculture materials. Temporal variation showed the highest abundance in April (49 particles) and the lowest in May (7 particles), likely influenced by rainfall-driven runoff and hydrodynamic changes. August recorded higher counts (37 particles), coinciding with active fishing during the southwest monsoon. Water samples consistently contained more microplastics than sediments, indicating buoyant particles' persistence in dynamic coastal systems. The presence of larger particles in sediments suggests potential long-term accumulation and ecological risk. This study provides baseline data on urban coastal microplastic pollution, highlighting anthropogenic sources and the need for continued monitoring, mitigation strategies and investigation into interactions between microplastics, heavy metals and biota in Johor's coastal environments.

Keywords— Johor Strait, marine pollution, microplastic, sediment, water

I. INTRODUCTION

Microplastics defined as plastic particles smaller than 5 mm, are among the most widespread and persistent pollutants in aquatic environments [1]. They originate from the breakdown of larger plastic debris or from direct use in industrial and domestic products. Once released, their buoyancy and resistance to degradation allow them to disperse widely, leading to accumulation in surface waters, sediments, and marine organisms [2], [3]. Coastal areas near urban centers are increasingly recognized as hotspots for microplastic contamination due to inputs from stormwater runoff, fishing activities, aquaculture and industrial effluents. Johor, a southern state of Peninsular Malaysia, borders both the Strait of Malacca and the South China Sea, and its coastal waters are heavily influenced by urbanization, port facilities and aquaculture farms [4], [5]. Recent studies highlight that estuaries and coastal wetlands are among the most vulnerable environments, acting as sinks for anthropogenic pollutants where fibres and fragments dominate microplastic assemblages due to hydrodynamic conditions and land-based inputs [6], [7]. This study focuses on Pendas, Johor Bahru which is located along the Johor Strait, a site under strong anthropogenic pressure. It aims to establish baseline evidence of microplastic contamination by assessing abundance, types, colours, and temporal variation in water and sediment from this urban-impacted coastal environment.

II. LITERATURE REVIEW

Microplastics enter aquatic environments through various pathways, most notably wastewater discharges, urban runoff, fishing activities and industrial effluents [8], [9]. Studies in Mediterranean Sea have reported anthropogenic fibres as the most prevalent category of microparticles, with cellulose and polyester dominating the water column, largely linked to textile production and fishing activities [10]. Research across marine environments shows that microplastics are dominated by fibres and fragments, typically originating from textiles, fishing gear, and packaging materials [11], [12], [13]. Recent reviews confirm that estuaries and coastal wetlands are particularly vulnerable, acting as sinks for anthropogenic pollutants where fibres and fragments dominate microplastic assemblages due to hydrodynamic conditions and land-based inputs [6], [7]. In Southeast Asia, rapid coastal urbanisation combined with weak waste management systems contributes significantly to improperly disposed plastic waste, with Malaysia generating an estimated 0.94 million tonnes of plastic waste annually, of which 0.4 million tonnes are mismanaged [14]. Comparable trends are observed regionally, fibres and polyethylene dominated surface waters in Thailand's Rayong province [15], while early evidence from Singapore confirmed polyethylene, polypropylene, and polystyrene in both sediments and seawater [16]. Around Pasaran Island in Indonesia, surface waters contained an average of 67 items/L, with fibres making up 72% of particles, mainly blue and black, and polypropylene identified as a key polymer [15]. Sediments function as long-term sinks for these contaminants, while water samples capture short-term variability [17], [18]. Global assessments also highlight that rapid urbanisation and poor waste management are key drivers of estuarine plastic loads, with direct implications for fisheries and aquaculture [19], [20]. Recent studies emphasise that microplastics and heavy metals pose combined risks to marine organisms, enhancing toxicity and bioaccumulation pathways [21],[22],[23].In Malaysia, limited studies have investigated microplastic contamination in coastal and estuarine waters, yet evidence points to significant inputs from urban and aquaculture activities in the Johor Strait [24], [25], [26], [27]. These findings highlight the Johor Strait as a critical urban-impacted site where focused assessments, such as the present study in Pendas, are essential to understand local pollution dynamics and inform management strategies.

III.RESEARCH METHODOLOGY

A. Study Area and Sampling Sites

The study was conducted in Pendas, Johor Bahru, located along the Johor Strait, southern Peninsular Malaysia (1°16'19.1"N, 103°35'8.2"E) (Fig. 1). This site was selected as it represents a highly urbanized coastal environment influenced by port activities, aquaculture and urban runoff. Sampling was carried out in March and August 2025 to capture temporal variability in microplastic contamination. Both surface water and sediment samples were collected during each sampling event.

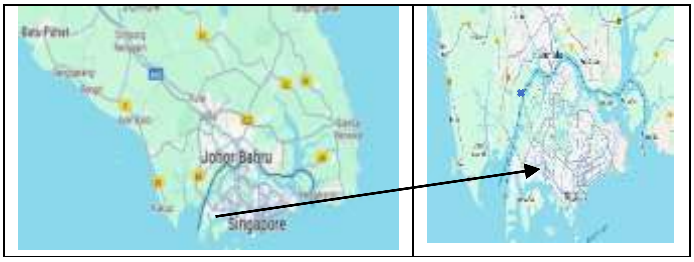

Fig. 1. Map showing the sampling location at Pendas, Johor Bahru, situated along the Johor Strait, southern Peninsular Malaysia, representing an urban-influenced coastal site impacted by port, aquaculture and urban runoff.

B. Sample Collection

Surface seawater samples were collected at each sampling point using a clean stainless-steel bucket. A total of 20 L of water was obtained and subsequently filtered through a 75 μm stainless-steel sieve. The retained residues were rinsed with deionised water into pre-cleaned glass bottles and preserved as samples [28]. Sediment samples were collected from the top 5 cm of the seabed using a stainless-steel grab sampler, transferred into aluminium containers [27], and transported under cooled, contamination-free conditions. All samples were stored at 4 °C in the laboratory until further processing.

C. Sample Digestion and Density Separation

Water and sediment samples were processed following a modified digestion and density separation protocol [23], [24]. For water samples, 30% hydrogen peroxide (H_2O_2) was added at a ratio of 10:1 (sample: reagent, v/v) in glass bottles to remove organic matter. The bottles were covered and incubated at 50 °C for 48 h. Sediment samples were oven-dried at 50 °C for 48 h, homogenised, and sieved through a 5 mm mesh to remove large debris. Subsamples (50 g dry weight) were transferred into clean glass beakers, and 150 mL of 30% H_2O_2 was added to digest organic material under the same incubation conditions.

After digestion, both water and sediment samples were subjected to density separation using saturated sodium chloride (NaCl, 1.2 g/cm³). The mixtures were stirred with a glass rod until homogenised and allowed to settle for 24 h. The supernatant was carefully collected and filtered through 0.45 μm filters using a vacuum pump. Filters were transferred into pre-cleaned glass petri dishes, wrapped with aluminium foil and dried at 50 °C for 24 h prior to microscopic examination. All procedures were conducted promptly to minimise airborne contamination, and equipment was handled under contamination-controlled conditions.

D. Identification of Microplastics

Suspected microplastic particles retained on the filters were observed under a stereomicroscope (Huvitz HSZ-600). Microplastics were classified by shape, size and colour. Selected particles were further analysed using Raman spectroscopy (spectral range: 200–4000 cm^{-1}) to confirm polymer composition. Identified spectra were compared against a polymer reference library following established protocols [29].

E. Water Quality Analysis

In-situ water quality parameters were measured during each sampling event using a portable YSI multiparameter probe. Parameters included temperature (°C), pH, salinity (ppt), and dissolved oxygen (mg/L). Measurements were taken at the same locations as water and sediment collection to provide supporting environmental context.

F. Quality Control and Contamination Prevention

To minimise contamination, all equipment was rinsed with filtered distilled water and wrapped in aluminium foil prior to use. Sample processing was conducted in a clean laboratory environment using glass and stainless-steel materials instead of plastics wherever possible. Procedural blanks were processed alongside samples to monitor potential contamination.

IV. FINDINGS AND DISCUSSION

A. Abundance and Types of Microplastics

A total of 101 microplastic particles were recorded across all samples collected from Pendas between March and August 2025. Fig 2 shown that water samples contained the majority (n = 86), while sediment samples accounted for 15 particles. Fibres were the most abundant type (71%, n = 72), followed by fragments (29%, n = 29). No films, beads, or foams were detected. Water samples consistently contained higher MP counts than sediment, indicating that lighter fibres and fragments are more likely to remain suspended in the water column. The predominance of fibres mirrors findings from other estuarine and coastal systems worldwide, reinforcing their persistence as the most mobile and bioavailable microplastic type with potential ingestion risks for fish and invertebrates that underpin local fisheries, and is consistent with studies in Brunei, Kazakhstan, and Indonesia where fibres and fragments dominated water and sediment samples [30],[31],[32].

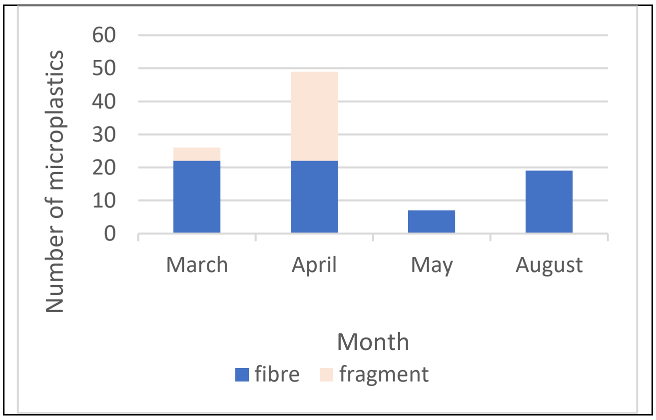

Fig. 2. Abundance and types of microplastics in water and sediment samples collected from Pendas, Johor Strait (March–August 2025). Fibres were dominant (71%), followed by fragments (29%), with water samples containing substantially higher counts than sediments.

B. Size Distribution and Morphology

Microscopic observations revealed marked differences in the morphology and size of microplastic particles collected from water and sediment samples at Pendas (Fig. 3). Fibres were generally elongated and thread-like, ranging from 0.6 to 3.9 mm, though some extended beyond 4 mm, with the largest fibre measuring 5.2 mm. Fragments appeared as irregular, angular particles and were mostly <2 mm in size. An isolated larger fragment measuring 9.5 mm was detected in April water samples, representing an outlier that substantially increased the mean size of fragments for that month. When comparing size distributions across sampling months and matrices, clear patterns emerged. In April water samples, fibres ranged between 0.58 and 5.18 mm (median ~1.65 mm), while fragments were generally smaller (median ~0.80 mm), indicating that most broken plastic debris entering the water column consisted of fine particles. Sediment collected in April contained only two fibres (0.8–2.65 mm), suggesting that although fewer in number, larger fibres tend to deposit and accumulate in benthic habitats.

By May, fibres in the water were much smaller (0.29–1.23 mm, median ~0.75 mm), indicating the dominance of fine secondary fibres. In contrast, fibres in the May sediment samples were larger (1.02–2.44 mm, median ~2.17 mm), reflecting the tendency of heavier or coarser fibres to settle more readily into the sediment. In August water samples, fibre sizes were broader (1.04–4.54 mm, median ~2.0 mm), with many particles falling within the 1–3 mm range. This shift suggests a mix of recently introduced fine particles and older, larger fibres persisting in the water column. Sediment in August contained only one fibre (1.57 mm), again supporting the pattern that larger fibres may preferentially settle into the benthic environment. Taken together, these results show that fibres were consistently dominant in all months, with typical sizes concentrated between 1 and 3 mm, while fragments were less common and usually <2 mm, except for rare larger outliers.

Similar dominance of fibre-shaped particles has been documented in estuarine and coastal waters of Southeast Asia, where fibres accounted for more than 70% of microplastics around Pasaran Island, Indonesia [17]. In Malaysia, evidence from fish samples such as the crescent perch (Terapon jarbua) also confirmed fibres as the predominant type ingested, further supporting their widespread occurrence and persistence in marine ecosystems. The comparison between matrices highlights that water contained more fine fibres and fragments, while sediment tended to retain fewer but slightly larger fibres. These patterns align with the understanding that microplastics undergo continuous input and resuspension in dynamic urban coastal waters, with sediment acting as a secondary sink for larger particles. The predominance of fibres, especially those in the 1–3 mm range, reflects strong contributions from fishing gear, ropes, textiles and packaging waste commonly associated with port and urbanised environments [11]. These results are significant because fine fibres within the 1–3 mm range are readily ingested by filter feeders and small fish, raising concerns for trophic transfer and seafood safety in regions dependent on aquaculture and coastal fisheries.

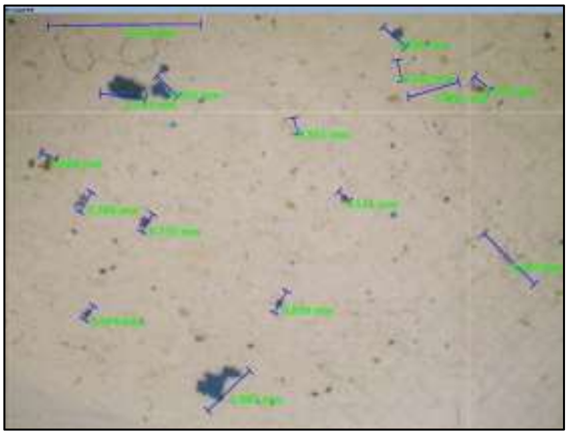

Fig. 3. Microscopic images of fibre and fragment shaped microplastics observed in Pendas water samples with size measurements showing fibres elongated (0.6–5.2 mm) and fragments irregular (<2 mm).

C. Colour Composition

Microplastic particles were identified in five colours: blue (47%), black (30%), transparent (16%), red (6%), and brown (1%) shown in Fig.4. The predominance of blue and black particles suggests strong inputs from urban and port-related activities, including textile effluents, fishing operations, and industrial discharges. Around Pasaran Island, Indonesia, blue and black were also the most observed colours, reflecting the influence of fishing and domestic activities [17]. Transparent particles are most likely derived from single-use packaging and containers, while the presence of red and brown particles can be linked to paints, coatings, or aquaculture equipment commonly used in coastal environments. The predominance of blue and black particles in Pendas is consistent with findings from the Anzali Wetland, Caspian Sea, where red, black, and blue were identified as the most frequent colours in both water and sediment samples, reflecting contributions from urban and industrial sources [33]. Global syntheses also indicate that darker colours, especially black, often reflect ageing and fragmentation of plastics, while blue particles are strongly associated with fishing gear and aquaculture activities [34]. These findings confirm that the dominance of blue and black particles is a common feature of urban-impacted marine ecosystems, driven by both land-based and maritime sources. The dominance of blue and black particles is not only indicative of fishing and textile activities, also highlights risks for misidentification by marine organisms that rely on visual cues, further amplifying ecological and health implications.

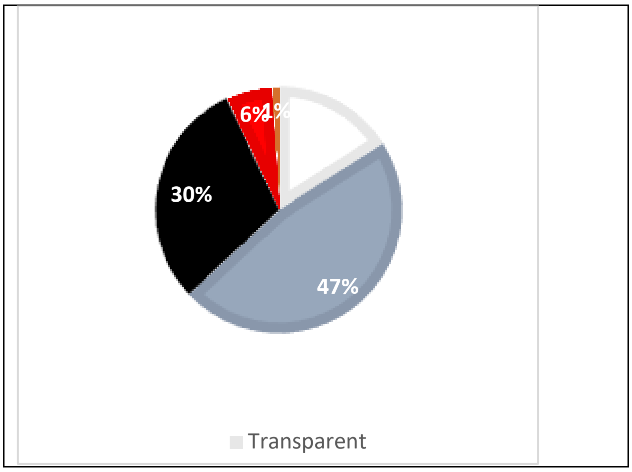

Fig. 4. Colour composition of microplastics identified in water and sediment samples from Pendas (March–August 2025). Blue (47%) and black (30%) particles were most prevalent, reflecting inputs from textiles, fishing gear and port-related activities.

D. Polymer Identification

Raman spectroscopy analysis confirmed that the dominant polymer types among selected particles were polyethylene (PE) and polypropylene (PP). Fig. 5 shown characteristic Raman bands for PE were detected near 1064, 1129, and 1295 cm⁻¹, corresponding to C–C stretching and CH_2 twisting, while PP was identified by peaks at 841, 973, and 1454 cm⁻¹ [28], [29], representing CH_3 rocking and symmetric CH_2 bending. These polymers are widely used in fishing gear, ropes, nets, and consumer packaging, consistent with the anthropogenic activities surrounding the Johor Strait. The identification of PE and PP in both water and sediment samples is consistent with findings from Malaysian coastal studies, where PP and PE were the most frequently reported polymers in microplastics from Sabah beaches [31]. Together, these results confirm the significant role of PE and PP as dominant pollutants in urbanised marine ecosystems. The identification of PE and PP as dominant polymers is consistent with global reports and underscores their persistence in aquatic food webs, where biofouling and sorption of contaminants can magnify ecological and human health risks.

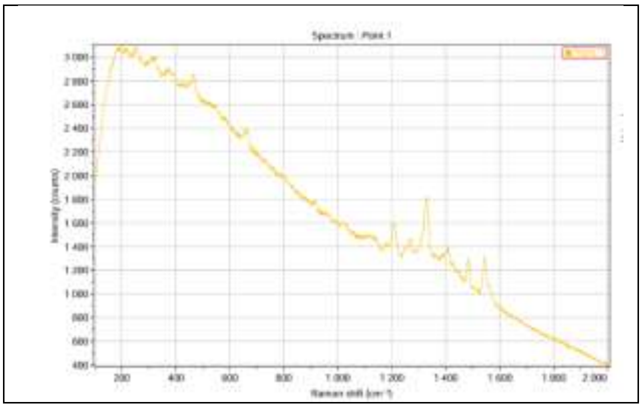

Fig. 5. Raman spectra confirming polyethylene (PE) and polypropylene (PP) as the dominant polymers in microplastic particles from Pendas, Johor Strait. PE peaks detected near 1064, 1129, and 1295 cm⁻¹; PP peaks at 841, 973, and 1454 cm⁻¹.

E. Temporal Variation

Microplastic abundance exhibited distinct temporal variability between March and August 2025. Fig. 6 shown the highest number of particles was detected in April 2025 with 49 microplastics, followed by August 2025 with 37 microplastics, while March 2025 with 24 microplastics and particularly May 2025 with 7 microplastics recorded lower counts. The sharp increase in April 2025 coincides with periods of heavier rainfall and enhanced surface runoff, which likely transported urban debris and textile-derived fibres into the Johor Strait. The marked decline in May may reflect calmer hydrodynamic conditions and reduced inputs, resulting in lower particle concentrations through dilution and sedimentation. By August, the abundance increased again, possibly linked to intensified fishing and aquaculture activities during the southwest monsoon.

These patterns align with documented seasonal hydrodynamics in Malaysian coastal waters. Along the east coast of Johor, inter-monsoon transitions have been shown to alter temperature, salinity, and dissolved oxygen, reflecting marked seasonal variability in water column properties [38]. Similarly, the formation of thermal frontal zones along the east coast of Peninsular Malaysia highlights how monsoon-driven circulation and stratification processes influence particle transport and accumulation [39]. These observations emphasise that microplastic loads are highly sensitive to both natural seasonal dynamics and human coastal activities reinforcing the need for long-term monitoring in urban-impacted waters. The temporal variability observed here parallels seasonal dynamics reported in other Asian estuaries, indicating that monitoring strategies must consider both natural hydrodynamics and pulses of human activity to effectively manage pollution loads.

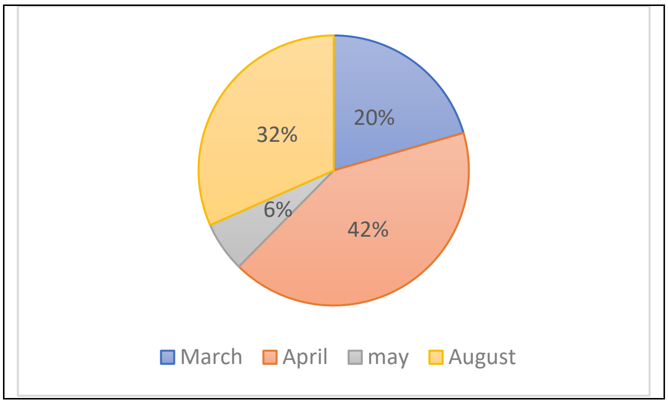

Fig. 6. Temporal variation of microplastic abundance in water and sediment from Pendas, Johor Strait (March–August 2025). Peak abundance was observed in April (49 particles) and August (37 particles), coinciding with rainfall and coastal activities, while May recorded the lowest (7 particles).

F. Relationship to Urban Influence

Microplastic patterns observed at Pendas are closely linked to the site's urbanised setting. The proximity of port facilities, aquaculture farms, and dense urban catchments provides multiple entry pathways for plastic debris into the Johor Strait. These inputs not only elevate concentrations in the water column but also create conditions for long-term accumulation in sediments, where particles can be remobilised by tidal currents and vessel traffic. Similar associations between coastal urbanisation and elevated microplastic loads have been reported across Southeast Asian estuaries, where land-based activities dominate the flux of marine debris [14], [40]. The evidence from Pendas reinforces that coastal development and human pressures are key drivers of microplastic contamination, with implications for benthic habitats, fisheries, and local aquaculture systems that rely on water quality and ecological resilience. This relationship between urbanisation and microplastic input carries direct implications for fisheries sustainability, aquaculture productivity and coastal management policies, reinforcing the need for integrated waste reduction and stricter discharge controls in rapidly developing coastal regions.

V. CONCLUSION

This study confirmed the presence of microplastics in surface water and sediment from Pendas, Johor Strait, establishing a critical baseline for monitoring in this urban-influenced coastal zone. Fibres were the dominant type, mainly blue and black, with polyethylene (PE) and polypropylene (PP) identified as the most common polymers. Temporal variation showed peaks in April and August, linked to rainfall-driven runoff and coastal activities, underscoring the combined influence of natural and anthropogenic factors.

These findings highlight that microplastic pollution is not only a scientific concern but also a pressing management issue with direct implications for fisheries, aquaculture and seafood safety. They underline the urgency of strengthening waste management, enforcing stricter controls on urban and aquaculture discharges and integrating microplastic indicators into national coastal monitoring frameworks. Importantly, the results provide evidence to support Malaysia's roadmap towards reducing single-use plastics and advancing integrated shoreline and estuary management.

Future studies should prioritise biological uptake in benthic organisms such as shrimp and explore interactions with heavy metals to better understand ecological risks and human exposure pathways. At the same time, proactive mitigation and policy interventions ranging from port-based waste reception facilities to public awareness campaigns are essential to reduce inputs at source and safeguard coastal ecosystem resilience.

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