



Investigation of Microplastic Pollution in Seawater and Copepods: A Case Study from Selangor Coastal Areas

Anis Hazwani Rosnizan¹ | Siti Rohana Mohd Yatim¹✉ | Nadiyah Wan Rasdi² | Nur Azalina Suzianti Feisal³ | Ahmad Razali Ishak¹

1. Centre for Environmental Health & Safety Studies, Faculty of Health Sciences, Universiti Teknologi Mara (UiTM), Cawangan Selangor, Kampus Puncak Alam, 42300 Puncak Alam, Selangor, Malaysia.

2. Faculty of Fisheries and Food Science, Universiti Malaysia Terengganu, 21300 Kuala Terengganu, Terengganu Malaysia.

3. Department of Diagnostic and Allied Health Science, Faculty of Health and Life Sciences, Management and Science University, Shah Alam 40150, Selangor, Malaysia.

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ABSTRACT

Marine ecosystems face a growing environmental threat from microplastic contamination. This study examines the presence of microplastics in seawater and marine copepods along the coast of Selangor, Malaysia. Surface water samples from Bagan Nakhoda (n=24) and Bagan Lalang (n=81) both contained microplastics. Microscopic analysis of the copepod *Oithona attenuata* showed ingested microplastics in individuals from Bagan Lalang (n=25) and Bagan Nakhoda (n=10). Most particles were fibers, with seawater microplastics averaging 1400 to 1600 µm, and copepod-ingested measuring 130 to 150 µm. Fourier-transform infrared (FTIR) analysis identified polyethylene terephthalate (PET), polypropylene (PP), and cellulose acetate (CA) in both seawater and copepod samples. These findings provided important information on pollution levels and microplastic composition in coastal habitats. The dominance of fiber-shaped particles in both seawater and organisms indicates a consistent contamination pattern. The observed particle size raises ecological concerns, especially when ingested by marine organisms. Overall, the results underscore the urgent need for further research and targeted mitigation strategies to better understand and address microplastic impacts in marine ecosystems.

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INTRODUCTION

Plastic waste is a major contributor to environmental pollution and poses significant public health concerns. Projections indicate that microplastic pollution in marine environments could triple by 2040 due to human activities and a limited awareness of its environmental impact (Rodríguez-Torres et al., 2022; Taha et al., 2021). Plastics constitute the largest component (24%) of municipal solid waste and are increasing at an annual rate of 2-3%, driven by rapid population growth, rising consumption, and industrial development, especially in urban centers. Microplastics, defined as plastic particles smaller than 5 mm, originate from the breakdown of larger plastic items. Their high surface area-to-volume ratio and hydrophobic properties enable them to adsorb harmful substances, including persistent organic pollutants (POPs) and metals (Bai et al., 2021). Microplastics exhibit diverse characteristics (spheres, beads, pellets,

*Corresponding Author Email: sitirohana@uitm.edu.my

foams, fibers, fragments, films, and flakes), colors, polymer types, and sizes (Taha et al., 2021). These properties influence their distribution, buoyancy, and sinking behavior of microplastics, ultimately determining their fate in marine ecosystems and contributing to biomagnification and bioaccumulation in marine organisms (Bank, 2022).

Due to their small size (1 μm to 5 mm), microplastics are easily ingested by marine organisms. Copepods, a dominant zooplankton group, may mistake microplastics for natural food sources such as microalgae and phytoplankton (Bai et al., 2021). They play a vital role in marine food webs, linking primary producers to higher trophic levels. Ingesting microplastics can disrupt physiological functions, including digestion, and may lead to developmental and reproductive issues (Taha et al., 2021; Wang et al., 2019). Microplastics can accumulate and biomagnify through the food chain from copepods to fish and other marine organisms, ultimately posing risks to human health (Setälä et al., 2014; Pironti et al., 2021; Puspa, 2023).

Previous studies, such as Taha et al. (2021), investigated microplastic pollution in Terengganu coastal waters, focusing on microplastic abundance and ingestion by copepods. Human activities, including fishing, tourism, shipping, and resource exploitation, exacerbate the microplastic pollution (Botterell et al., 2022; Beaumont et al., 2019). Improper disposal of plastic waste, widespread use of fishing nets, and increased tourism-related waste contribute significantly to this issue (Maione, 2021; Billard & Boucher, 2019; Jambek et al., 2015). This study aims to assess microplastic pollution in seawater and copepods along the Selangor coast, providing essential data to support mitigation strategies for environmental and public health protection.

MATERIALS AND METHODS

Study and Sampling Areas

Selangor, one of Malaysia's most urbanized states, experiences high levels of pollution, including microplastic contamination in its coastal waters. The state was selected due to its dense population, rapid development, and substantial waste generation. Two coastal districts were examined: Sepang (5° 25' 59.99" N, 100° 22' 59.99" E) and Sabak Bernam (3° 45' 59.99" N, 100° 52' 59.99" E). Sepang has mixed industrial, commercial, transportation, and residential activities. In contrast, Sabak Bernam is dominated by small-scale fishing, agriculture, and tourism.

Samples Collection

Following Khalik et al. (2018) and Amin et al. (2020), seawater and copepod samples were collected at both locations. Two sample types were obtained: (1) seawater for microplastic analysis and (2) marine copepods for ingestion analysis. A 20 μm mesh plankton net (30 cm mouth diameter, 55 cm length) was towed at 5 to 10 m depth for approximately 15 minutes at each site. Samples were transferred into 1 L seawater bottles and preserved with 4% buffered formaldehyde. Sampling was repeated three times per site to ensure sufficient volume for laboratory analysis. Copepod samples were collected using the same method. The volume of water filtered during plankton net tows was calculated using the formula: $V = \pi r^2 \times L$, where r is the net mouth radius (15 cm), and L is the tow length estimated from GPS tracking during sampling. After each tow, the collected seawater was homogenised by gentle swirling, and 100-mL aliquots were subsampled for microplastic analysis. The use of 100-mL aliquots was necessary to prevent filter clogging due to high particulate matter and to allow replicate filtration per tow while maintaining a manageable laboratory processing time.

Observation and Identification of Microplastics

Microplastic concentrations in seawater were calculated as: Total microplastic count /

Total volume of filtered water (Wei et al., 2022). Polymer composition was determined using attenuated total reflectance Fourier Transform Infrared (FTIR) spectroscopy. Absorption bands were compared with the SpectraBase™ database (John Wiley & Sons, Inc.) for polymer identification.

For ATR-FTIR analysis, particles were selected based on size (>100 µm), shape (fibers and fragments), and color diversity to ensure representative sampling from each site and sample type (seawater and copepods). A total of 30 spectra were analyzed: 20 from seawater samples (10 per site) and 10 from copepod-ingested particles (5 per site). Representative spectra are shown in Figure 5. Polymer identification was validated using match scores ³ 70%, following standard FTIR practices.

Microplastics Analysis in Seawater

Microplastics in seawater were characterized by their size, color, and shape. Each 1-liter sample underwent a two-step filtration process. First, 100 ml aliquots were filtered using a vacuum pump and a 0.45 µm glass microfiber filter (Whatman Sterile Cellulose Nitrate Membrane, 47 mm diameter), with filters monitored to prevent clogging and rinsed with deionized water. The filters were then transferred into a conical flask and treated with 30% hydrogen peroxide (H₂O₂), followed by digestion in a 60°C water bath for 24 hours. After digestion, the samples were filtered again using the same procedure, and the resulting filters were placed in petri dishes for visual examination under a stereomicroscope (ZEISS Stemi 305) and a Dino-Lite Edge digital microscope (5MP AM7915 Series). Polymer types were subsequently confirmed using FTIR spectroscopy.

Microplastic Extraction in Copepods

Methodology followed Outram et al. (2020) and Aytan et al. (2022). Copepods were identified using an inverted microscope with verification from marine biologists at Universiti Malaysia Terengganu (UMT). Preserved samples were sieved through a 200 µm mesh and rinsed with ultrapure water. From each location, 145 to 150 individuals were counted. A total of 110 to 120 *Oithona attenuate* copepods per location were isolated in 20 mL glass vials for digestion. Copepods were digested with hot 65% nitric acid (HNO₃) at 80°C for 30 minutes. Digested samples were filtered using 0.22 µm glass fiber membranes and examined under a stereomicroscope (ZEISS Stemi 305), supported by Dino-Lite Edge (5MP AM7915 Series) imaging and FTIR spectroscopy for polymer confirmation. The digestion of copepods using 65% nitric acid (HNO₃) at 80°C for 30 minutes was selected based on validated protocols. This method effectively removes organic matter without degrading microplastic particles, particularly fibers and fragments. Alternative enzymatic digestion methods were considered but not applied due to resource constraints.

Quality Assurance and Quality Control

To minimize contamination, only non-plastic materials were used, including cotton lab coats, nitrile or latex gloves, and glassware (Lin et al., 2018). All equipment was thoroughly rinsed with distilled water before use. Quality control measures were applied throughout the analytical workflow to reduce contamination and verify the reliability of the methods. Laboratory blanks were included with each batch of seawater and copepod samples and were subjected to the same filtration and digestion procedures, but without environmental material. Most blanks contained no detectable microplastics; on the few occasions where one or two fibres appeared, these counts were deducted from the corresponding samples, and the possibility of minor airborne contamination is noted as a study limitation. Method performance was further assessed through spike-and-recovery trials.

Table 1. Microplastic counts for shape, color size, and density of each sampling location

MP Counts	Bagan Lalang	Bagan Nakhoda
Shapes		
Fibers	20	69
Film	1	6
Fragment	3	6
Colour		
Black	11	36
Blue	12	25
Red	1	4
Green	0	11
Purple	0	2
Orange	0	3
Total Counted Microplastic	24.0	81.0
Mean (\pm SD) Particle Size (μm)	1483.91 (\pm 415.15)	1599.32 (\pm 464.05)
Mean (\pm SD) of Particles Density	24.0 (\pm 10.75)	81.0 (\pm 23.30)

Statistical Analysis

Data was analyzed using SPSS version 29.0. The Mann-Whitney U test ($p < 0.05$) was applied to compare microplastic densities between two locations, while Spearman correlation was used to assess the relationship between microplastic concentration in seawater and ingestion levels in copepods. FTIR spectral data were visualized using Origin Pro 2024, and descriptive statistics as well as data tabulation were completed using Microsoft Excel.

RESULTS AND DISCUSSION

Abundance of Microplastics in Seawater and Marine Copepods

This study examined microplastic pollution in two Selangor coastal sites - Bagan Lalang and Bagan Nakhoda. A clear difference in microplastic density was observed between the locations. Bagan Nakhoda recorded a significantly higher concentration (81.0 ± 23.30 particles/L⁻¹) compared to Bagan Lalang (24.0 ± 10.75 particles/L⁻¹). These values also exceeded previously documented levels in other Malaysian coastal areas, such as Port Dickson (4.65 particles/L⁻¹), Terengganu (0.3 to 1.45 particles/L⁻¹), Kuala Nerus (.13 to 0.69 particles/L⁻¹), and Kuantan Port (0.14 to 0.15 particles/L⁻¹) (Zainuddin et al., 2023; Khalik et al., 2018).

A Mann-Whitney U test confirmed a significant difference between the two sites ($U = 100.0$, $p < 0.001$). This variation is likely influenced by differences in land use and economic activities. Microplastic distribution is known to be shaped by human activity, local geography, and seasonal dynamics (Liu et al., 2022). For instance, tourism contributes substantially to coastal microplastics loads (Gül, 2023), while agricultural activities may enhance fragmentation and transport (Wei et al., 2022). Microplastics can enter marine systems through terrestrial runoff, groundwater pathways, river discharge, and direct inputs from human activities, further redistributed by coastal hydrodynamics such as currents and tides (Machado et al., 2018; Zainuddin et al., 2022).

Microplastic Ingestion in Marine Copepods

Only one copepod species, *Oithona attenuata*, was identified at both sampling sites (Figure 1), consistent with previous regional records (Da Rosa et al., 2019; Balqiah & Rahim, 2021). This study is the first to report microplastic ingestion in *O. attenuata*. Despite higher seawater microplastic density in Bagan Nakhoda (10 particles). This corresponds to ingestion densities of 0.045 particles ind⁻¹ and 0.011 particles ind⁻¹, respectively. These ingestion levels fall within the range reported for various copepod species globally (Amin et al., 2020; Aytan et al., 2022; Kosore et al., 2018; Zavala-Alarcon et al., 2023).

A significant difference in ingestion between locations was detected ($p = 0.038$, Mann-Whitney $U = 23.0$). Several factors influence this pattern, including zooplankton feeding behavior, gut passage time, microplastic vertical distribution, and particle availability (Botterell et al., 2022; Taha et al., 2021). Vertical transport models indicate that particle size and buoyancy determine whether microplastics float, sink, or remain suspended, affecting their encounter rates with zooplankton.

Composition and Characteristics of Microplastics in Seawater

Microplastics in seawater differed in color, size, and shape (Figures 2 and 3). Bagan Llang exhibited three color categories, while Bagan Nakhoda showed six. At both sites, fibers were the dominant shape, consistent with regional trends reported in Malaysian estuarine and offshore waters (Taha et al., 2021) and international studies such as the Black Sea (Aytan et al., 2022; Zainuddin et al., 2022).

The average particle sizes were $1483.91 \pm 415.15 \mu\text{m}$ in Bagan Lalang and $1599.32 \pm 464.05 \mu\text{m}$ in Bagan Nakhoda. These values align with the size range reported in other marine environments (Aytan, 2022; Wei et al., 2022). Dominant colors varied by location: blue and black fibers were common in Bagan Lalang, while black, blue, and green dominated in Bagan Nakhoda. These patterns likely reflect local sources such as fishing gear, textile fibers, and tourism-related litter (Khalik et al., 2018; Zainuddin et al., 2022).

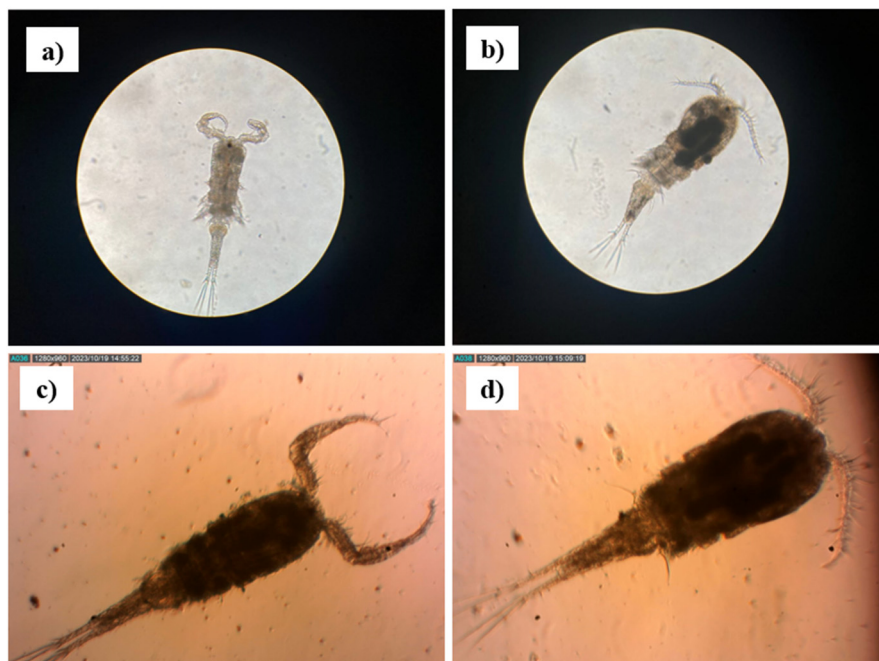


Fig. 1. Marine copepods from both sampling locations a) – c): *O. attenuata* (Male) and b) – d): *O. attenuata* (Female)

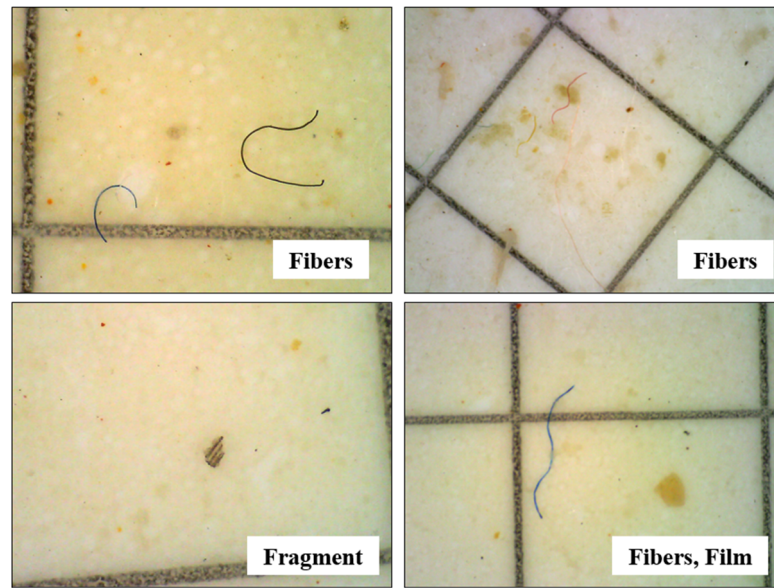


Fig. 2. The different morphotypes and colors of microplastics obtained from the seawater of Bagan Lalang and Bagan Nakhoda

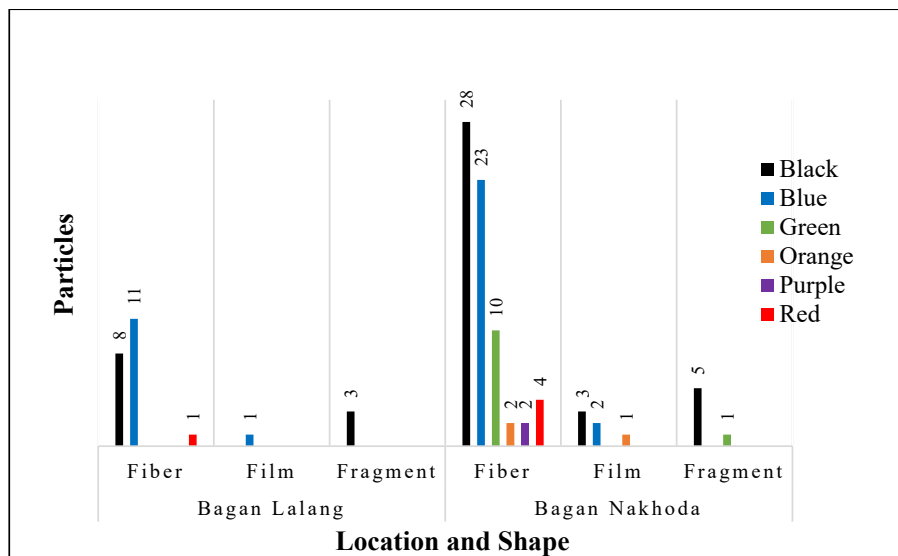


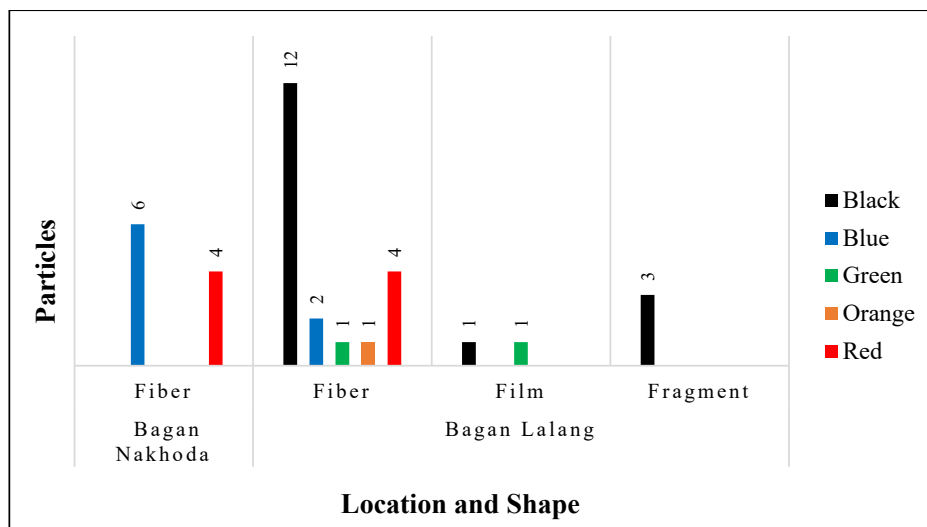
Fig. 3. Microplastic counts that contrast between shape and color in both locations

Composition of Microplastics Ingested by Copepod

Microplastic ingestion varied by gender (Table 2). In Bagan Lalang, males ingested 16 microplastics and females ingested 9. In Bagan Nakhoda, males ingested 7 and females 3. The average size of ingested microplastics was in Bagan Lalang ($149.58 \pm 57.18 \mu\text{m}$) and Bagan Nakhoda ($125.23 \pm 43.61 \mu\text{m}$). These sizes are larger than those ingested by some copepod species, such as *C. hyperboreus* ($11.0 - 20.0 \mu\text{m}$) and *A. clausi* ($38.0 \mu\text{m}$), indicating species-specific feeding characteristics (Gerhardt et al., 2020). Figure 4 shows that fibers were the dominant ingested morphotype. Unlike many copepod studies, where fragments are more commonly ingested (Aytan et al., 2022; Erni-Cassola et al., 2019; Botterel et al., 2022), *O. attenuate* in this study predominantly consumed fibers, similar to findings off Terengganu (Karbalaeei et al. 2019). This may be attributed to the high abundance of suspended fibers in the water column (Taha et al., 2021), increasing the likelihood of encounter and ingestion.

Table 2. Ingested microplastics by copepods different in gender from different areas

MP Counts	Bagan Lalang		Bagan Nakhoda	
	<i>O. attenuata</i> (Male)	<i>O. attenuata</i> (Female)	<i>O. attenuata</i> (Male)	<i>O. attenuata</i> (Female)
No. of Individuals	58	57	55	55
Shapes				
Fibers	13	8	7	3
Film	0	2	0	0
Fragment	3			
Colour				
Black	13	3		
Blue	1	1	4	2
Red	1	3	3	1
Green		2		
Orange	1			
Total Ingested Microplastic	16	9	7	3
Density of Ingested MPs (Particles Individual ⁻¹)	0.011		0.045	
Mean (\pm SD)	146.15	155.68	132.99	113.61
Particle Size (μ m)	(\pm 63.39)	(\pm 46.98)	(\pm 53.94)	(\pm 23.59)

**Fig. 4.** Ingested Microplastic by *O. attenuata* counts, which contrasts between shape and colour in both locations

In terms of color, Bagan Nakhoda copepods primarily ingested blue ($n = 6$) and red ($n = 4$) fibers, while those from Bagan Lalang predominantly ingested black fibers ($n = 12$). These preferences mirror patterns reported in other copepods species, suggesting shared visual or sensory biases (Amin et al., 2020).

Microplastic Polymers Types

Attenuated Total Reflectance-Fourier Transform Infrared (ATR-FTIR) analysis in Figure 5 confirmed the presence of three main polymers: polyethylene terephthalate (PET), dominant in Bagan Lalang, polypropylene (PP), dominant in Bagan Nakhoda, and cellulose acetate (CA) detected in Bagan Nakhoda. PET and PP are widely reported in marine environments due to their

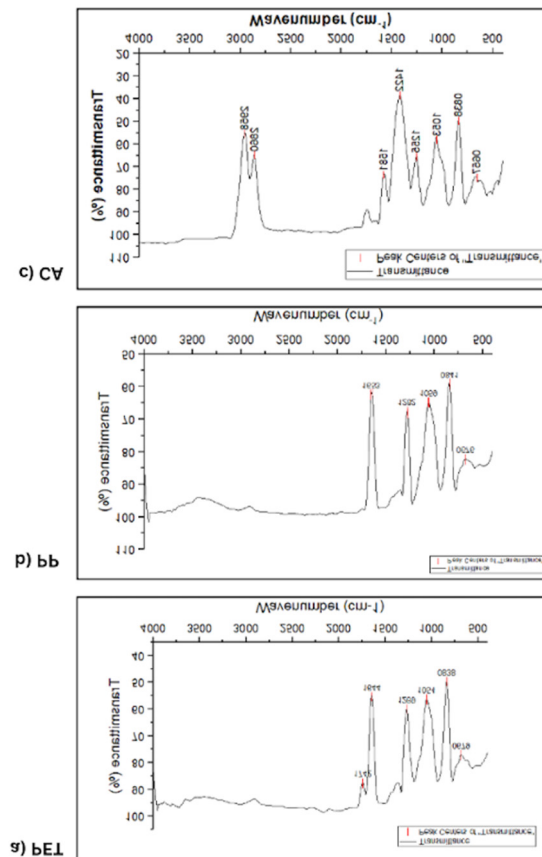


Fig. 5. FTIR spectra of the representative microplastic found in Bagan Lalang and Bagan Nakhoda. a) PET; b) PP; c) CA

Table 3. Spearman's Rank Correlation Analysis

		MP Density in Seawater	Ingested MP in Copepod
MP Density in Seawater	Correlation Coefficient	1.000	-0.505
	Sig. (2 tailed)		0.023
	N	20	20
Ingested MP in Copepod	Correlation Coefficient	-0.505	1.000
	Sig. (2 tailed)	0.023	
	N	20	20

common use and degradation properties (Dimassi et al., 2023). PET sources likely include fishing nets and food packaging (Stanica-Ezeanu & Matei, 2021). PP originates from short-lived plastic items such as food containers and disposable masks (Kokalj et al., 2022; Martinelli et al., 2021). Cellulose acetate (CA), often used in biodegradable products, persists depending on environmental conditions (Yadav & Hakkarainen, 2022). The ingestion of PET and PP by zooplankton aligns with documented patterns in copepods and fish larvae (Sipps et al., 2022; Zavala-Alarcón et al., 2023).

Correlation between Seawater Microplastics and Copepod Ingestion

Table 3 indicates an unexpected inverse relationship between seawater microplastic density and copepod ingestion. Bagan Lalang, despite lower seawater microplastic levels, showed a higher ingestion rate. A moderate but significant negative correlation was observed (Spearman's

$r = -0.505$, $p = 0.023$).

This contrasts with findings from Terengganu (Taha et al., 2021) and the Black Sea (Aytan et al., 2022), where higher ambient microplastic levels generally corresponded to increased ingestion. The inverse trend observed here may relate to the feeding strategy of *O. attenuate*, which functions as an ambush feeder (Rodríguez-Torres et al., 2022). Ambush feeders rely on passive encounters rather than active filtering. As such, ingestion is more likely influenced by particle behavior, hydrodynamics, and collision probability rather than surrounding concentration alone.

The Selangor coastline exhibits substantial microplastic contamination, with Bagan Nakhoda showing a higher seawater microplastic density. However, *Oithona attenuata* ingested more microplastics in Bagan Lalang, likely to species-specific feeding mechanisms. The dominance of fibers and the presence of PET, PP, and CA highlight multiple pollution sources. These findings demonstrate complex interactions between microplastic availability, copepod feeding strategies, and local anthropogenic pressures, emphasizing the need for continued monitoring and ecological risk assessment.

CONCLUSION

This study confirmed the presence of microplastics along the Selangor coastline, an area with limited prior research. Microplastic concentrations varied between sites, with Bagan Nakhoda showing a higher seawater microplastic density than Bagan Lalan, highlighting localized variability in contamination. Fibers were the predominant shape, followed by fragments, and the average particle size was below 2000 μm . In addition to seawater analysis, microplastic ingestion by *Oithona attenuata* copepods was examined. Interestingly, ingestion rates did not correspond directly to ambient microplastic concentrations: copepods from Bagan Lalang, despite lower seawater microplastic density, exhibited higher ingestion rates. This pattern indicates that ingestion may be influenced by factors beyond environmental concentration, such as species-specific feeding strategies such as ambush feeding, hydrodynamic conditions, and particle characteristics.

There was a moderate negative correlation between seawater microplastic density and copepod ingestion (Spearman's $p = -0.505$, $n = 20$, $p = 0.023$). However, this relationship should not be interpreted as causal. Encounter probability, particle buoyancy, and localized ecological conditions likely play a more significant role than concentration alone. These findings underscore the complexity of microplastic dynamics in marine ecosystems and the need for caution when interpreting correlational data. Future research should incorporate controlled experiments and ecological risk assessments, including bioaccumulation and biomagnification across trophic levels, to better understand these interactions.

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The present research did not receive any financial support.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct,

data fabrication and/ or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

REFERENCES

- Amin, R. M., Sohaimi, E. S., Anuar, S. T., & Bachok, Z. (2020). Microplastic ingestion by zooplankton in Terengganu coastal waters, southern South China Sea. *Marine Pollution Bulletin*, 150, 110616.
- Aytan, Ü., Esensoy, F., & Şentürk, Y. (2022). Microplastic ingestion and egestion by copepods in the Black Sea. *Science of the Total Environment*, 806, 150921.
- Bai, Z., Wang, N., & Wang, M. (2021). Effects of microplastics on marine copepods. *Ecotoxicology and Environmental Safety*, 217, 112243.
- Balqiah, B., & Rahim, A. A. (2021). An updated checklist of marine copepods from Peninsular Malaysia with notes on their functional traits and distributional records. *Borneo Journal of Marine Science and Aquaculture*, 5(1), 08–24.
- Bank, M. S. (2022). Microplastic in the environment: Pattern and process. In *Environmental contamination remediation and management*. Springer Publishing.
- Beaumont, N. J., Aanesen, M., Austen, M. C., Börger, T., Clark, J. R., Cole, M., ... & Wyles, K. J. (2019). Global ecological, social and economic impacts of marine plastic. *Marine Pollution Bulletin*, 142, 189-195.
- Billard, G., & Boucher, J. (2019). The challenges of measuring plastic pollution. DOAJ (DOAJ: Directory of Open Access Journals).
- Botterell, Z. L. R., Bergmann, M., Hildebrandt, N., Krumpfen, T., Steinke, M., Thompson, R. F., & Lindeque, P. K. (2022). Microplastic ingestion in zooplankton from the Fram Strait in the Arctic. *Science of the Total Environment*, 831, 154886.
- Da Cruz Lopes Da Rosa, J., Monteiro-Ribas, W. M., Batista, L. L., & De Almeida Fernandes, L. D. (2019). First record of *Oithona attenuata* Farran, 1913 (Crustacea: Copepoda) from Brazil. *Nauplius*, 27.
- De Souza Machado, A. A., Kloas, W., Zarfl, C., Hempel, S., & Rillig, M. C. (2018). Microplastics as an emerging threat to terrestrial ecosystems.
- Dimassi, S. N., Hahladakis, J. N., Yahia, M. N. D., Ahmad, M. I., Sayadi, S., & Al-Ghouti, M. A. (2023). Insights into the degradation mechanism of PET and PP under marine conditions using FTIR. *Journal of Hazardous Materials*, 447, 130796.
- Erni-Cassola, G., Zadjelovic, V., Gibson, M. I., & Christie-Oleza, J. A. (2019). Distribution of plastic polymer types in the marine environment; A meta-analysis. *Journal of Hazardous Materials*, 369, 691–698.
- Fibbe, M. C., Carroll, D., Gowans, S., & Siuda, A. N. S. (2023). Ingestion of microplastics by copepods in Tampa Bay Estuary, FL. *Frontiers in Ecology and Evolution*, 11.
- Gül, M. R. (2023). Short-term tourism alters the abundance, size, and composition of microplastics on sandy beaches. *Environmental Pollution*, 316, 120561.
- Gerhardt, A., Schaefer, M., Blum, T., & Honnen, W. (2020). Toxicity of microplastic particles with and without adsorbed tributyltin (TBT) in *Gammarus fossarum* (Koch, 1835). *Fundam Appl Limnol*, 194(1), 57-65.
- Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., ... & Law, K. L. (2015). Plastic waste inputs from land into the ocean. *science*, 347(6223), 768-771.
- Jaspe, B. T. (2020). Abundance, distribution, and species composition of cyclopoid copepods along a transect traversing the upwelling zone off northern Zamboanga peninsula, Philippines. *Asian Fisheries Science*, 33(4).
- Karbalaei, S., Golieskardi, A., Hamzah, H., Abdulwahid, S. N., Hanachi, P., Walker, T. R., & Karami, A. (2019). Abundance and characteristics of microplastics in commercial marine fish from Malaysia. *Marine Pollution Bulletin*, 148, 5–15.
- Khalik, W. M. a. W. M., Ibrahim, Y. S., Anuar, S. T., Govindasamy, S., & Baharuddin, N. F. (2018). Microplastics analysis in Malaysian marine waters: A field study of Kuala Nerus and Kuantan.

- Marine Pollution Bulletin, 135, 451–457.
- Kokalj, A. J., Dolar, A., Drobne, D., Marinšek, M., Dolenc, M., Škrlep, L., Strmljan, G., Mušič, B., & Škapin, A. S. (2022). Environmental hazard of polypropylene microplastics from disposable medical masks: acute toxicity towards *Daphnia magna* and current knowledge on other polypropylene microplastics. *Microplastics and Nanoplastics*, 2(1).
- Kosore, C., Ojwang, L., Maghanga, J., Kamau, J., Kimeli, A., Omukoto, J., ... Ndirui, E., 2018. Occurrence and ingestion of microplastics by zooplankton in Kenya's marine environment: first documented evidence. *African Journal of Marine Science*, 40 (3), 225–234.
- Lin, W., Li, X., Yang, M., Lee, K., Chen, B., & Zhang, B. (2018). Brominated Flame retardants, microplastics, and Biocides in the Marine Environment: Recent updates of occurrence, analysis, and impacts. In *Advances in Marine Biology* (pp. 167–211). Elsevier BV.
- Liu, H., Wang, X., Shi, Q., Liu, Y., Lei, H., & Chen, Y. (2022). Microplastics in arid soils: Impact of different cropping systems (Altay, Xinjiang). *Environmental Pollution*, 303, 119162.
- Maione, C. (2021). Quantifying plastics waste accumulations on coastal tourism sites in Zanzibar, Tanzania. *Marine Pollution Bulletin*, 168, 112418.
- Martinelli, L., Kopilaš, V., Vidmar, M., Heavin, C., Machado, H., Todorović, Z., Buzás, N., Pot, M., Prainsack, B., & Gajović, S. (2021). Face masks During the COVID-19 Pandemic: A simple protection tool with many meanings. *Frontiers in Public Health*, 8.
- Outram, L., Hurley, J., Rott, A. S., Crooks, N., & Pernetta, A. P. (2020). No evidence of microplastic consumption by the copepod, *Temora longicornis* (Müller, 1785) in Chichester Harbour, United Kingdom. *Nauplius*, 28.
- Pironti, C., Ricciardi, M., Motta, O., Miele, Y., Proto, A., & Montano, L. (2021). Microplastics in the environment: intake through the food web, human exposure and toxicological effects. *Toxics*, 9(9), 224.
- Puspa, M. D. S. I. D. N. W. (2023, January 26). Masyarakat perlu cakra kesan buruk sisa plastik marin. *Berita Harian*. Retrieved April 4, 2023, from
- Rodríguez-Torres, R., Almeda, R., Xu, J., Hartmann, N. B., Rist, S., Brun, P., & Nielsen, T. G. (2022). The behavior of planktonic copepods minimizes the entry of microplastics in marine food webs. *Environmental Science & Technology*, 57(1), 179–189.
- Setälä, O., Fleming-Lehtinen, V., & Lehtiniemi, M. (2014). Ingestion and transfer of microplastics in the planktonic food web. *Environmental pollution*, 185, 77-83.
- Sipps, K., Ar buckle-Keil, G., Chant, R. J., Fahrenfeld, N., Garzio, L., Walsh, K., & Saba, G. (2022). Pervasive occurrence of microplastics in Hudson-Raritan estuary zooplankton. *Science of the Total Environment*, 817, 152812. *Pacific Environmental Pollution*, 319, 120994.
- Stanica-Ezeanu, D., & Matei, D. (2021). Natural depolymerization of waste poly (ethylene terephthalate) by neutral hydrolysis in marine water. *Scientific Reports*, 11(1).
- Taha, Z., Amin, R. M., Anuar, S. T., Nasser, A. A., & Sohaimi, E. S. (2021). Microplastics in seawater and zooplankton: A case study from Terengganu estuary and offshore waters, Malaysia. *Science of the Total Environment*, 786, 147466.
- Wang, J., Li, Y., Lu, L., Zheng, M., Zhang, X., Tian, H., ... & Ru, S. (2019). Polystyrene microplastics cause tissue damages, sex-specific reproductive disruption and transgenerational effects in marine medaka (*Oryzias melastigma*). *Environmental Pollution*, 254, 113024.
- Wei, Y., Ma, W., Xu, Q., Sun, C., Wang, X., & Gao, F. (2022). Microplastic distribution and influence factor analysis of seawater and surface sediments in a typical bay with diverse functional areas: a case study in Xincun Lagoon, China. *Frontiers in Environmental Science*, 10.
- Yadav, N., & Hakkarainen, M. (2022). Degradation of cellulose acetate in simulated aqueous environments: One-Year Study. *Macromolecular Materials and Engineering*, 307(6).
- Zahari, N. Z., Vincent, S., Cleophas, F., Budin, K., & Sabullah, M. K. (2023). Abundance, distribution, and characterization of microplastics on two recreational beaches in Kota Kinabalu, Sabah, Malaysia. *Water*, 15(15), 2681.
- Zainuddin, A. H., Aris, A. Z., Zaki, M., Yusoff, F. M., & Wee, S. Y. (2022). Occurrence, potential sources, and ecological risk estimation of microplastic towards coastal and estuarine zones in Malaysia. *Marine Pollution Bulletin*, 174, 113282.
- Zavala-Alarcón, F. L., Huchin-Mian, J. P., Del Pilar González-Muñoz, M., & Kozak, E. R. (2023). In situ microplastic ingestion by neritic zooplankton of the central Mexican Pacific. *Environment Pollution*, 319, 120994.