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Microplastic contamination in wild oysters, coastal water, and sediment in Rayong Province, Thailand: Distribution, characteristics, and estimated dietary exposure

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ABSTRACT

Microplastic contamination in edible bivalves and their surrounding environments is increasingly concerning because it links environmental pollution to potential dietary exposure. This study examined microplastic abundance, particle characteristics, and polymer composition in wild oysters (*Saccostrea* sp.), surface water, and sediment from two contrasting sites in Rayong Province, Thailand: marine-influenced Noen Kho (NK) and freshwater-influenced La Won Canal (LW). Sixty adult oysters and associated water and sediment samples were collected from eight stations. Microplastics were extracted using chemical digestion and density separation, characterized by shape and size, and a randomly selected subset was identified by micro-Fourier transform infrared (μ-FTIR) spectroscopy. Microplastics occurred in all matrices. Mean abundance was 4.13 ± 2.55 particles/g wet weight in oysters, 1.37 ± 0.28 particles/L in water, and 466.67 ± 199.76 particles/kg dry weight in sediment. Abundance in water and sediment was significantly higher at LW than at NK ($p < 0.01$), whereas oysters showed no significant between-site difference. Particles <250 μm predominated, with fragments and fibers as the major morphologies. Within the FTIR-analyzed subset, PP and PE/LDPE occurred more frequently at LW, whereas PET represented a larger proportion at NK. Under the mean per-capita consumption scenario, estimated annual dietary exposure ranged from 888 to 1009 particles/person/year and was substantially higher under a high-consumption scenario. These findings show that spatial patterns differed among matrices, identify oyster consumption as a potential dietary exposure pathway, and indicate that exposure estimates depend on the consumption rate applied.

Keywords: wild oysters, microplastic abundance, polymer composition, coastal contamination, dietary exposure.

INTRODUCTION

Rising plastic production and use, along with inadequate waste management, have led to persistent inputs of plastic debris into aquatic environments (Galvão et al., 2020; Kumar et al., 2021). Through physical, chemical, and biological weathering, larger plastic debris can fragment into microplastics, commonly defined as plastic particles smaller than 5 mm (Andrady, 2011). Their persistence, small size, and widespread occurrence enable microplastics to transfer among water, sediment, and aquatic organisms, raising concerns about environmental contamination and human exposure through seafood consumption.

Coastal and estuarine environments are particularly relevant to microplastic contamination because they receive inputs from terrestrial and marine activities and are influenced by processes such as tidal exchange, sedimentation, and resuspension (Lebreton et al., 2017; Qian et al., 2021). These processes can affect microplastic transport and distribution among environmental compartments, while particle characteristics such as size, shape,

and polymer type further influence their environmental behavior (Kooi et al., 2017; Zhang et al., 2021). Assessing microplastics in water, sediment, and biota simultaneously can therefore provide a more integrated understanding of their occurrence and spatial distribution in coastal systems.

Oysters are suspension-feeding bivalves that continuously filter particles from surrounding water and may therefore ingest microplastics in their habitat (Ma et al., 2017). Studies have reported microplastics in oysters from numerous coastal regions, with measured abundances varying considerably across studies. For example, reported values range from relatively low concentrations in oysters from South Korea to substantially higher concentrations at some coastal sites in the United States (Cho et al., 2019; Wontor et al., 2023). Such variability may reflect differences in local environmental conditions and anthropogenic inputs. However, comparisons are also influenced by differences in sampling, extraction procedures, particle-size detection limits, and polymer-identification methods. Because oysters are consumed as whole soft tissues, microplastics in edible oysters are also relevant to assessing potential dietary exposure.

Marine plastic pollution is a major environmental concern in Thailand, where plastic waste enters rivers, estuaries, and coastal waters from multiple land- and sea-based activities (Babel et al., 2020; Meijer et al., 2021). Previous studies have documented microplastics in Thai coastal waters and in several commercially important shellfish species, including mussels, cockles, gastropods, and oysters (Akkajit et al., 2023; Hongsawat et al., 2024; Imasha and Babel, 2023; Phaksopa et al., 2023; Ruairuen et al., 2022; Ta et al., 2022; Thushari et al., 2017). However, studies simultaneously examining wild oysters and their surrounding water and sediment remain limited, particularly along the eastern coast of Thailand. Consequently, it remains unclear whether spatial differences in environmental microplastic contamination are similarly reflected in edible wild oysters. Integrated assessment across these environmental and biological compartments can clarify the distribution of microplastics in coastal systems and inform source-control, pollution-reduction, and environmental management efforts.

Rayong Province supports coastal fisheries, aquaculture, tourism, and local seafood consumption, making it an appropriate setting for investigating microplastic contamination across environmental and biological matrices. This study addresses the identified knowledge gap by characterizing microplastics in wild oysters (*Saccostrea* sp.), surface water, and sediment from two contrasting coastal and estuarine environments and by estimating potential dietary exposure through oyster consumption. Accordingly, the objectives were to (i) determine the abundance and characteristics of microplastics in wild oysters, surface water, and sediment; (ii) compare spatial patterns of microplastic contamination between the two study sites; and (iii) estimate potential dietary exposure to microplastics through oyster consumption. This integrated approach provides site-specific evidence on the distribution of microplastics across environmental compartments and edible biota in an important coastal area of eastern Thailand.

MATERIALS AND METHODS

Study area and sampling strategy

This study was conducted at two ecologically significant coastal and estuarine sites in Klaeng District, Rayong province, Thailand: Noen Kho sub-district area (NK) and La Won Canal (LW). Both sites support small-scale fisheries and aquaculture, particularly oyster and shrimp farming, and are relevant to the local seafood supply. Sampling was conducted over two consecutive days in March 2024 during the dry season to provide a spatially comparable snapshot of microplastic contamination under similar seasonal conditions at the two study sites. The dry-season sampling period was selected based on a previous study in Thailand indicating seasonal variation in microplastic contamination in bivalves, with higher abundances reported during the dry season (Ruangpanupan et al., 2023).

We established four sampling stations at each site (S1–S4 in NK and S5–S8 in LW), as shown in Figure 1. Thirty adult oysters (*Saccostrea* sp.) with shell sizes of 4–5 cm, corresponding to commonly marked size, were randomly collected from each sampling site (n = 60). After collection, samples were wrapped in aluminum foil, transported in cooled containers, and stored at 4 °C until processing. All samples were processed within two weeks of collection, ensuring data reliability.

Surface water and sediment samples were collected from the same stations. At each station, we collected three spatial replicates approximately

30 m apart, yielding 12 water and 12 sediment samples per site. For water sampling, we passed 10 L of surface water through a 75-µm stainless-steel sieve. The retained material was rinsed into clean glass containers. Temperature, pH, dissolved oxygen (DO), and salinity were measured in situ using a multiparameter probe (HandyLab 680). Sediment samples (0–5 cm depth) were collected using a stainless-steel Birge–Ekman grab sampler following National Oceanic and Atmospheric Administration guidelines (NOAA, 2015). Approximately 500 g of sediment was collected per sample, wrapped in aluminum foil, and stored at 4 °C before analysis.

Microplastic extraction

The microplastic extraction protocol from oyster soft tissue followed Hongsawat et al. (2024). Oyster shells were rinsed with distilled water to remove external debris, and the soft tissues were carefully removed and weighed. Samples were digested with 69% nitric acid (HNO_3) at room temperature overnight, then heated to 60 °C until the organic tissue was completely digested. Density separation was then performed using saturated sodium chloride (NaCl; approximately 1.2 g/cm^3). After settling for 24 h, the supernatant was vacuum-filtered through Whatman GF/C filters (1.2-µm pore size). Before analysis, filters were dried and kept in covered glass Petri dishes.

For water samples, material retained by the 75-µm sieve was treated with 30% hydrogen peroxide (H_2O_2) at 60 °C with periodic agitation to effectively remove organic matter. Density separation was subsequently performed using saturated NaCl solution, followed by settling and vacuum filtration through GF/C filters (Prarat and Hongsawat, 2022; Thushari et al., 2017).

Sediment samples were first oven-dried and sieved (<5 mm). A representative dry subsample was treated with H_2O_2 to remove organic matter, then density-separated using NaCl solution (Prarat et al., 2024). After settling, the supernatant was filtered using the same protocol as described for oyster samples.

Microplastic characterization

Visual analysis

Filters were systematically examined under a stereomicroscope (Nikon Eclipse E200) at 7.5×–45× magnification. Suspected microplastics were classified according to morphology as fibers, fragments, films, or foams. Particle sizes were grouped into six categories: <250, 250–500, >500–750, >750–1000, >1000–2000, and >2000–3000 µm. Because water samples were pre-concentrated using a 75-µm sieve, particles smaller than 75 µm were not represented in the water samples.

Polymer identification

A total of 120 suspected microplastic particles were randomly selected for polymer identification. At each sampling site (NK and LW), 20 particles were selected from two samples of each matrix (oyster, surface water, and sediment), with 10 particles randomly selected per sample. Polymer identification was performed using micro-Fourier transform infrared spectroscopy (µ-FTIR; Thermo Scientific Nicolet iS5) in attenuated total reflectance (ATR) mode. Spectra were collected over 675–4000 cm^{-1} using 32 scans at a resolution of 8 cm^{-1} and compared with the OMNIC Picta spectral library. Polymer identity was accepted when the spectral match exceeded 70% (Addo et al., 2022).

Quality assurance and control

We implemented contamination control measures during sampling and analysis, including rinsing equipment with pre-filtered distilled water, air-drying, and covering with aluminum foil. Non-plastic equipment was used when possible, and personnel wore lab coats and nitrile gloves. All distilled water was pre-filtered through GF/C filters (1.2 µm pore size) to minimize contamination.

Procedural blanks were processed alongside the samples to assess laboratory contamination, reinforcing our commitment to data accuracy. Six procedural blanks were included for oyster samples and three each for water and sediment samples. Mean particle counts in procedural blanks were 0.70 ± 0.64 particles for oysters, 0.67 ± 0.58 particles for water, and 0.33 ± 0.58 particles for sediment.

Data analysis

Microplastic abundance was expressed as mean ± standard deviation. Oyster abundance was reported as particles/individual and particles

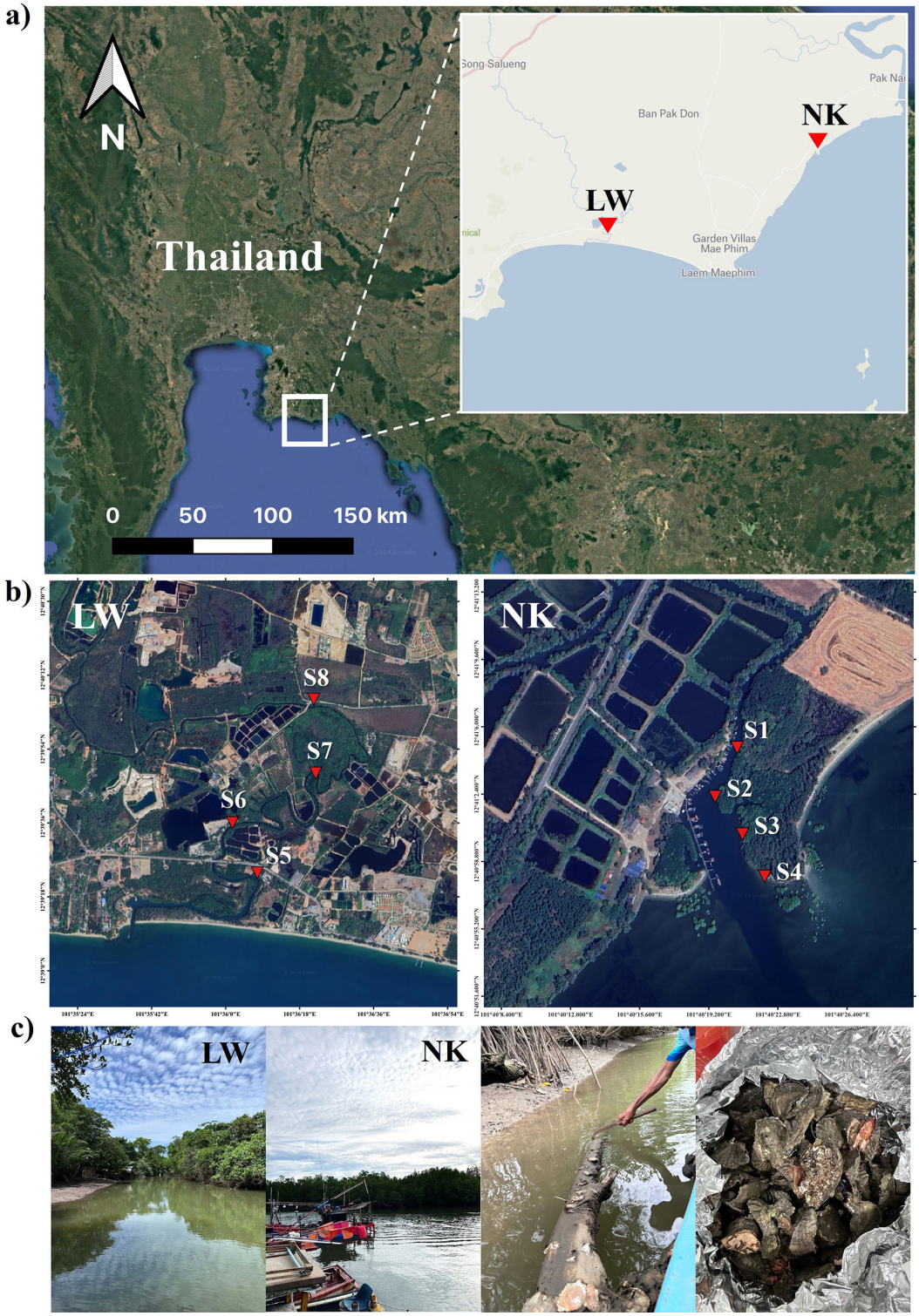

Figure 1. Study area and sampling overview: (a) locations of the two sampling sites, Noen Kho (NK) and La Won Canal (LW), in Rayong Province, Thailand; (b) distribution of sampling stations (S1–S8) within the study areas; and (c) representative views of the natural habitats of wild oysters, sampling activities, and collected oyster samples

per gram wet weight (particles/g w.w.). In contrast, water and sediment abundances were expressed as particles/L and particles per kg dry weight (particles/kg d.w.), respectively.

Statistical analyses were conducted using SPSS version 25.0, with significance set at $p < 0.05$. Normality was tested with the Shapiro–Wilk test. Differences in microplastic abundance

between NK and LW were evaluated with an independent-samples *t*-test when data were normal. The correlation between oyster soft-tissue wet weight and microplastic burden was assessed using Spearman's rank correlation due to non-normal distribution. Microplastic burden was expressed as total particles/individual, excluding mass-normalized abundance to avoid mathematical coupling.

Estimated dietary exposure to microplastics

Potential dietary exposure to microplastics through oyster consumption was estimated as the Estimated Annual Intake (EAI; particles/person/year), following approaches used in previous bivalve exposure studies (Expósito et al., 2022; Fang et al., 2019; Wakkaf et al., 2020), as shown in Equation 1.

$$EAI = C_O \cdot IR \cdot 365 \quad (1)$$

where: C_O is the mean microplastic abundance in oyster soft tissue (particles/g w.w.), and IR is the ingestion rate (g/person/day).

The primary exposure scenario used an IR of 0.63 g/person/day for Thai young adults aged 18.0–34.9 years, obtained from the National Bureau of Agricultural Commodity and Food Standards, Ministry of Agriculture and Cooperatives, Thailand (ACFS, 2016). This value was selected because it represented the highest mean ingestion rate among the reported age groups. Because this per-capita mean includes both consumers and non-consumers, it may underestimate exposure among oyster consumers. Therefore, an additional high-consumption scenario was evaluated using the 97.5th-percentile ingestion rate of 6.60 g/person/day. The EAI represents potential dietary exposure and should not be interpreted as a quantitative assessment of human health risk.

RESULTS AND DISCUSSION

Environmental conditions during sampling

Table 1 summarizes the environmental conditions at the sampling stations. Environmental conditions were generally comparable within each site but differed markedly between NK and LW. Salinity showed the most pronounced contrast, being substantially higher at NK (29.30–29.40 ppt) than at LW (0.00–0.61 ppt), indicating marine conditions at NK and freshwater-influenced conditions at LW. Similarly, pH was higher at NK (7.82–7.88) than at LW (6.81–7.30), whereas water temperature was lower at NK (29.0–29.5 °C) than at LW (31.0–34.0 °C). Dissolved oxygen showed relatively small differences between sites (6.86–7.03 mg/L at NK and 7.11–7.16 mg/L at LW). Across all sampling stations, the highest and lowest salinities were recorded at NK-S3 and LW-S8, respectively, while the corresponding pH extremes occurred at NK-S1 and LW-S6. The highest temperature was recorded at LW-S8 and the lowest at NK-S1–S3, whereas dissolved oxygen reached its maximum at LW-S5 and LW-S7 and minimum at NK-S2.

Because particle properties and hydrodynamic conditions govern microplastic transport and fate in coastal systems (Zhang, 2017), these environmental contrasts provide context for interpreting the spatial patterns of microplastic abundance described below.

Table 1. Geographic coordinates and environmental conditions at the sampling stations during March 2024

Sampling site	Station	Latitude (°N)	Longitude (°E)	Temperature (°C)	pH	DO (mg/L)	Salinity (ppt)
NK	S1	12.684600	101.672400	29.0	7.88	6.91	29.30
	S2	12.683900	101.672100	29.0	7.82	6.86	29.30
	S3	12.683300	101.672500	29.0	7.84	7.03	29.40
	S4	12.682700	101.672800	29.5	7.84	6.96	29.30
LW	S5	12.656111	101.602222	31.0	7.30	7.16	0.60
	S6	12.659722	101.600278	31.0	6.81	7.11	0.61
	S7	12.663056	101.606222	31.0	6.83	7.16	0.60
	S8	12.656111	101.606111	34.0	6.88	7.14	0.00

Microplastic abundance in oysters, water, and sediment

Microplastics were detected in all sample matrices, including oysters, surface water, and sediment. In oyster soft tissues, individual microplastic burden ranged from 4 to 19 particles/individual, with an overall mean of 9.28 ± 2.97 particles/ individual. When normalized to tissue wet weight, microplastic abundance ranged from 1.29 to 14.47 particles/g w.w., with an overall mean of 4.13 ± 2.55 particles/g w.w. Oysters from LW showed slightly higher mass-normalized abundance (4.39 ± 2.34 particles/g w.w.) than those from NK (3.86 ± 2.76 particles/g w.w.) (Figure 2a); however, the difference was not statistically significant (independent-samples *t*-test, $t(58) = -0.801$, $p = 0.427$). Thus, microplastic abundance in oyster tissues was comparable between the two sites. In addition, oyster soft-tissue wet weight was not significantly associated with individual microplastic burden (Spearman's $\rho = 0.043$, $p = 0.743$, $n = 60$), providing no evidence of a relationship between tissue mass and the number of microplastic particles detected per individual.

In contrast, environmental microplastic abundance differed significantly between sites. In surface water, microplastic abundance was 1.22 ± 0.20 particles/L at NK and 1.53 ± 0.27 particles/L at LW, with significantly higher abundance at LW (independent-samples *t*-test, $t(22) = -3.182$, $p = 0.004$). Similarly, sediment abundance was 316.67 ± 64.35 particles/kg d.w. at NK and 616.67 ± 173.79 particles/kg d.w. at LW (independent-samples *t*-test, $t(22) = -5.608$, $p < 0.001$) (Figure 2b, c). Salinity alone cannot explain this spatial pattern. Increasing salinity can modify particle behavior by influencing aggregation, effective density, and interactions with suspended matter, thereby affecting settling dynamics (Malli et al., 2022). In estuarine water, increased ionic strength promotes flocculation of microplastics with fine-grained sediment, and settling velocities have been reported to be 5 to 21 times higher than in freshwater (Laursen et al., 2023). Higher salinity may also reduce particle mobility and promote sediment accumulation (Zhang et al., 2024). On this basis, greater sedimentary accumulation would be expected under the saline conditions at NK. The opposite pattern, with higher abundance in both water and sediment at the low-salinity LW site, therefore, suggests that other site-specific factors outweighed salinity effects.

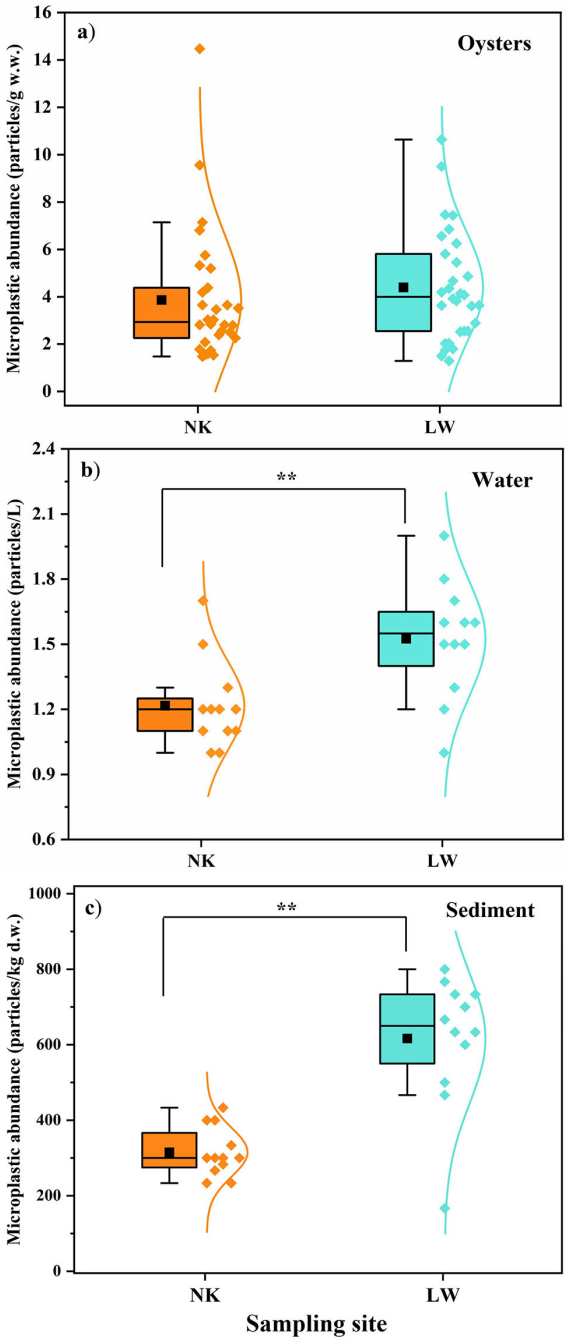

Figure 2. Box plots with individual data points and density curves showing microplastic abundance at NK and LW in (a) oysters, (b) surface water, and (c) sediment. Solid squares and horizontal lines within the boxes indicate the mean and median, respectively. Boxes represent the 25th and 75th percentiles, and whiskers indicate the 5th and 95th percentiles. In panels (b) and (c), asterisks (**) indicate statistically significant differences between sites ($p < 0.01$)

First, the freshwater-influenced conditions at LW indicate exposure to riverine or canal discharge, which is a major pathway for land-based plastic inputs to coastal waters (Lebreton et al., 2017).

Second, local hydrodynamics may have enhanced retention at LW. Weak hydrodynamics favor the formation of microplastic accumulation zones (Chubarenko et al., 2025), and denser particles are more likely to become trapped under low-discharge conditions (Defontaine et al., 2020), which is consistent with the dry-season sampling period. Conversely, the more dynamic coastal circulation at NK may have diluted and redistributed particles. However, because hydrodynamic conditions were not measured and environmental parameters co-varied with sampling sites during a single sampling campaign, these explanations remain inferential. Accordingly, temperature, pH, salinity, and dissolved oxygen were interpreted as site-specific environmental context rather than direct predictors of microplastic abundance.

Although microplastic abundance was higher in water and sediment at LW, oyster microplastic abundance did not differ significantly between sites. This suggests that biological processes such as filtration, particle selection, retention, and depuration, which influence the number of particles retained in tissues (Ward and Kach, 2009; Zhu et al., 2021), may modulate microplastic burden in oysters. Understanding these biological factors is crucial for interpreting spatial variability and assessing oysters' potential as bioindicators of environmental microplastic contamination.

Table 2 summarizes reported microplastic abundances in oysters from different geographic regions and environmental settings. Direct comparisons among studies should be interpreted cautiously, as reported abundances may be influenced by differences in sampling design, digestion and separation procedures, particle-size detection limits, and polymer identification methods. The mean abundance observed in the present study in Rayong Province, Thailand (4.13 ± 2.55 particles/g w.w.), was higher than values reported in several coastal regions, including Danang Bay, Vietnam (1.88 ± 1.58 particles/g w.w.; Do et al., 2022), northern Taiwan (0.70 ± 0.40 particles/g w.w.; Chen et al., 2023), Sri Lanka (1.23 ± 0.12 particles/g w.w.; Guruge et al., 2024), and the Mediterranean basin (1.98 ± 0.89 particles/g w.w.; Papini and Rakaj, 2025). A relatively comparable abundance was reported along the Taiwan coastlines (3.24 ± 1.02 particles/g w.w.; Liao et al., 2021), whereas higher concentrations were documented along the coastline of China (6.64 ± 6.95 particles/g w.w.; Lin et al., 2024) and the Mississippi Gulf Coast, USA (4.7 ± 0.25 to 30.7 ± 11.5 particles/g w.w.; Wontor et al., 2023).

These comparisons indicate that the microplastic abundance measured in oysters from Rayong falls within the broad range reported for oysters from other coastal environments. Differences among studies may reflect both site-specific environmental conditions and methodological variability. Local anthropogenic activities, wastewater inputs, fisheries, and aquaculture can contribute plastic debris to coastal environments. Regional differences in plastic production, population density, and waste management practices also contribute to spatial heterogeneity in contamination levels (Lebreton et al., 2017). In this context, the microplastic abundance observed in oysters from Rayong Province may be linked to local anthropogenic activities and the broader presence of plastic debris in Southeast Asian coastal environments.

The presence of microplastics in oysters, surface water, and sediment highlights the importance of controlling plastic inputs before they fragment and disperse across environmental compartments. Source-oriented measures, including reducing plastic consumption, improving waste segregation and collection, and preventing plastic leakage into aquatic environments, remain fundamental for limiting the generation and release of microplastics (Lee et al., 2025). For microplastics already in aquatic systems, treatment-based approaches may provide complementary control measures. Recent studies highlight the potential of nature-based adsorbents, including biochar, hydrochar, and activated carbon derived from agricultural residues, to remove micro- and nanoplastics from water (Essien et al., 2025; Mohsenzadeh et al., 2025). However, most adsorption-based studies have been conducted under controlled laboratory conditions, and their performance under complex environmental water matrices requires further evaluation.

Coagulation–flocculation, particularly when combined with other treatment processes, can further enhance particle removal (Tang et al., 2022). A recent meta-analysis covering 509 full-scale wastewater treatment plants reported median cumulative microplastic removal efficiencies of approximately 84% after secondary treatment and 95% after tertiary treatment (Zoccali et al., 2025). Advanced final-stage technologies, including membrane bioreactors, rapid sand filtration, and dissolved air flotation, have also achieved high removal efficiencies under full-scale conditions (Talvitie et al., 2017). Nevertheless, smaller

microplastics are generally more difficult to remove and may remain in treated effluents, allowing wastewater discharges to continue contributing microplastics to receiving waters (Zoccali et al., 2025). Therefore, adsorption-based and engineered treatment approaches should complement, rather than replace, source-control and waste-management measures that prevent plastic inputs into coastal environments.

Characterization of microplastics

Microplastic shape

Figure 3a illustrates the distribution of microplastic shapes in oysters, surface water, and sediment. Fragments and fibers were the predominant particle types across all matrices, although their relative proportions varied between sites. In oysters, fragments dominated at NK (69.26%), whereas fibers were predominant at LW (75.45%). A similar pattern was observed in water, with fragments dominating at NK (60.93%) and fibers at LW (55.19%). In contrast, sediment samples at both sites were consistently dominated by fragments (72.44% at NK and 72.07% at LW). Films were detected only at low proportions (0.45–1.64%), while foam was not detected in any matrix.

The predominance of fragments and fibers is consistent with patterns frequently reported in oysters and other coastal environments (Barboza et al., 2018; Cole et al., 2011; Li et al., 2016). Fragment-dominated profiles have been reported in oysters from several coastal regions (Do et al., 2022; Liao et al., 2021; Lin et al., 2024; Mladinich et al., 2024), whereas fiber-dominated profiles have also been observed in areas affected by diverse coastal anthropogenic activities (Austria-Ortíz et al., 2026; Doan et al., 2023; Guruge et al., 2024). This variability suggests

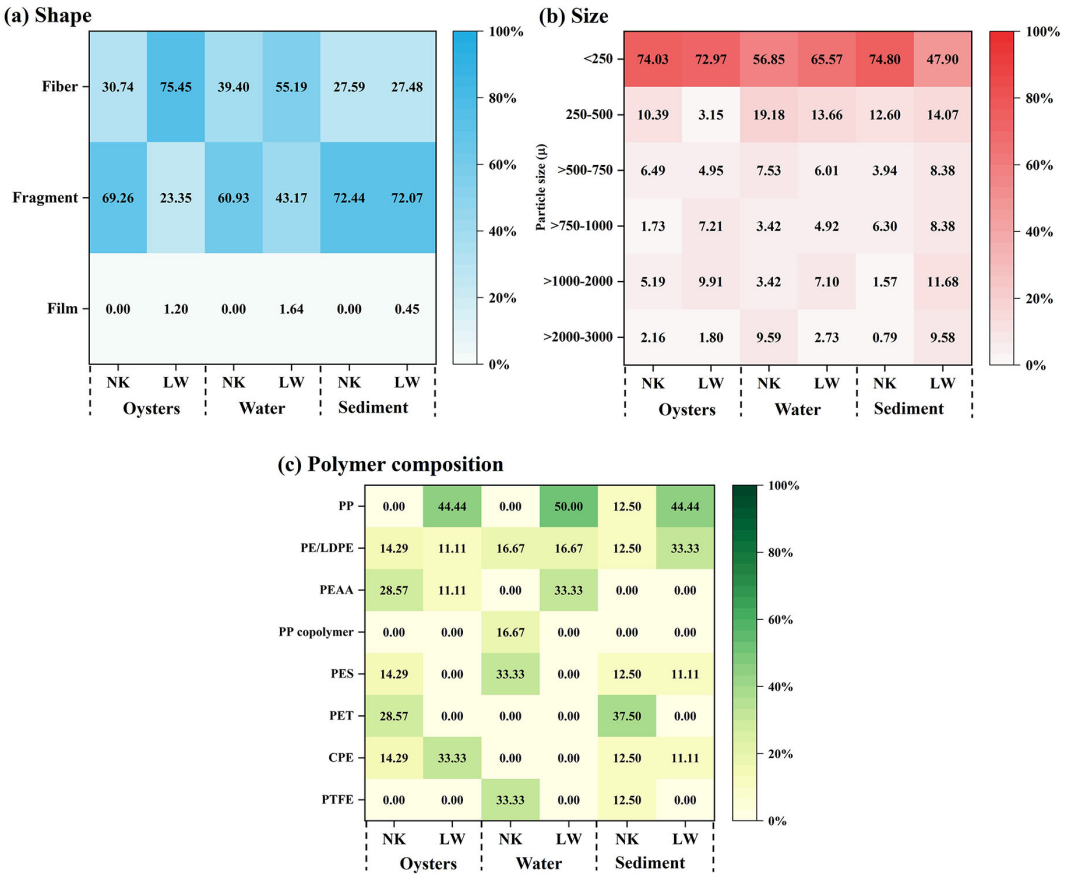

Figure 3. Heatmaps showing the percentage distributions of microplastic characteristics in oysters, surface water, and sediment at the NK and LW sampling sites: (a) particle shape, (b) particle size, and (c) polymer composition identified by μ-FTIR. Abbreviations: PP, polypropylene; PE, polyethylene; LDPE, low-density polyethylene; PEAA, poly(ethylene-co-acrylic acid); PP copolymer, propylene–ethylene copolymer; PES, polyester; PET, polyethylene terephthalate; CPE, chlorinated polyethylene; and PTFE, polytetrafluoroethylene

that microplastic morphology may differ by location, depending on environmental availability and local transport processes.

Particle shapes may influence microplastic transport and biological availability. Fragments commonly result from the breakdown of larger plastic debris, whereas fibers may remain suspended in the water column and remain available to suspension-feeding organisms. Previous studies also indicate that particle morphology can affect bivalve capture and retention (Mladinich et al., 2022; Ward et al., 2019). These environmental and biological factors may contribute to the predominance of fragment- and fiber-shaped microplastics observed in oyster tissues.

Microplastic size

Particle size is an important factor influencing microplastic transport, environmental fate, and bioavailability to aquatic organisms. Figure 3b illustrates the size distribution of microplastics across the three matrices. Particles <250 µm were the most abundant size class across all matrices, accounting for 72.97–74.03% in oysters, 56.85–65.57% in water, and 47.90–74.80% in sediment. The 250–500 µm fraction was generally the second most abundant size class (10.39–19.18%), except in oysters from LW, where it accounted for only 3.15%. Because water samples were preconcentrated using a 75-µm sieve, the <250 µm category in water represents particles in the approximately 75–250 µm size range recovered by the sampling procedure.

The predominance of smaller microplastics in oyster tissues may partly reflect the particle-selection characteristics of suspension-feeding bivalves. Particle size can influence capture and retention during filtration, while larger particles may be more readily rejected as pseudofeces (Evan Ward and Shumway, 2004; Ward et al., 2019). However, the observed size distribution likely reflects both biological filtration and the size distribution of particles available in the surrounding environment. Similar patterns have been reported in oysters from other coastal regions, including Brazil, Taiwan, and Vietnam, where relatively small particles, frequently within the sub-300 µm range, were commonly observed (Chen et al., 2023; Do et al., 2022; Oliveira et al., 2024).

The predominance of smaller particles may also be environmentally relevant because microplastic size influences suspension behavior, surface interactions, and potential biological exposure. Smaller particles generally have a higher surface area-to-volume ratio and may interact more readily with surrounding contaminants (Wang et al., 2020). They may act as vectors for transporting hazardous substances and, after ingestion, increase toxicological risks to marine organisms (Brennecke et al., 2016; Zhang et al., 2015). Therefore, the predominance of small microplastics observed in this study may increase exposure and potential health risks for marine organisms in these coastal environments.

Polymer composition

Figure 3c presents the polymer composition of the FTIR-analyzed particles. Eight synthetic polymer categories were identified: polypropylene (PP), polyethylene/low-density polyethylene (PE/LDPE), poly(ethylene-co-acrylic acid) (PEAA), propylene–ethylene copolymer (PP copolymer), polyester (PES), polyethylene terephthalate (PET), chlorinated polyethylene (CPE), and polytetrafluoroethylene (PTFE). Representative particles and their corresponding FTIR spectra are shown in Figure 4. As polymer identification was performed on a subset of recovered particles, the reported proportions reflect only the FTIR-analyzed fraction. They should not be interpreted as the polymer composition of all particles detected in each matrix.

Polymer profiles varied among sampling sites and matrices. In oysters from NK, PEAA and PET each accounted for 28.57% of the identified polymers, followed by PE/LDPE, PES, and CPE (14.29% each). In contrast, PP predominated in oysters from LW (44.44%), followed by CPE (33.33%). In water samples, PES and PTFE were the most frequently identified polymers at NK (33.33% each), whereas PP dominated at LW (50.00%), followed by PEAA (33.33%). In sediment, PET was the most abundant polymer at NK (37.50%), while PP (44.44%) and PE/LDPE (33.33%) predominated at LW.

The presence of PP and PE/LDPE at LW aligns with the widespread use and environmental presence of polyolefins in coastal settings, including materials associated with packaging, fisheries, and aquaculture (Andrady, 2011). Previous work in Rayong coastal waters has also reported PE and PP among the most detected polymers (Prarat and Hongsawat, 2022). However, polymer identity alone is insufficient to assign

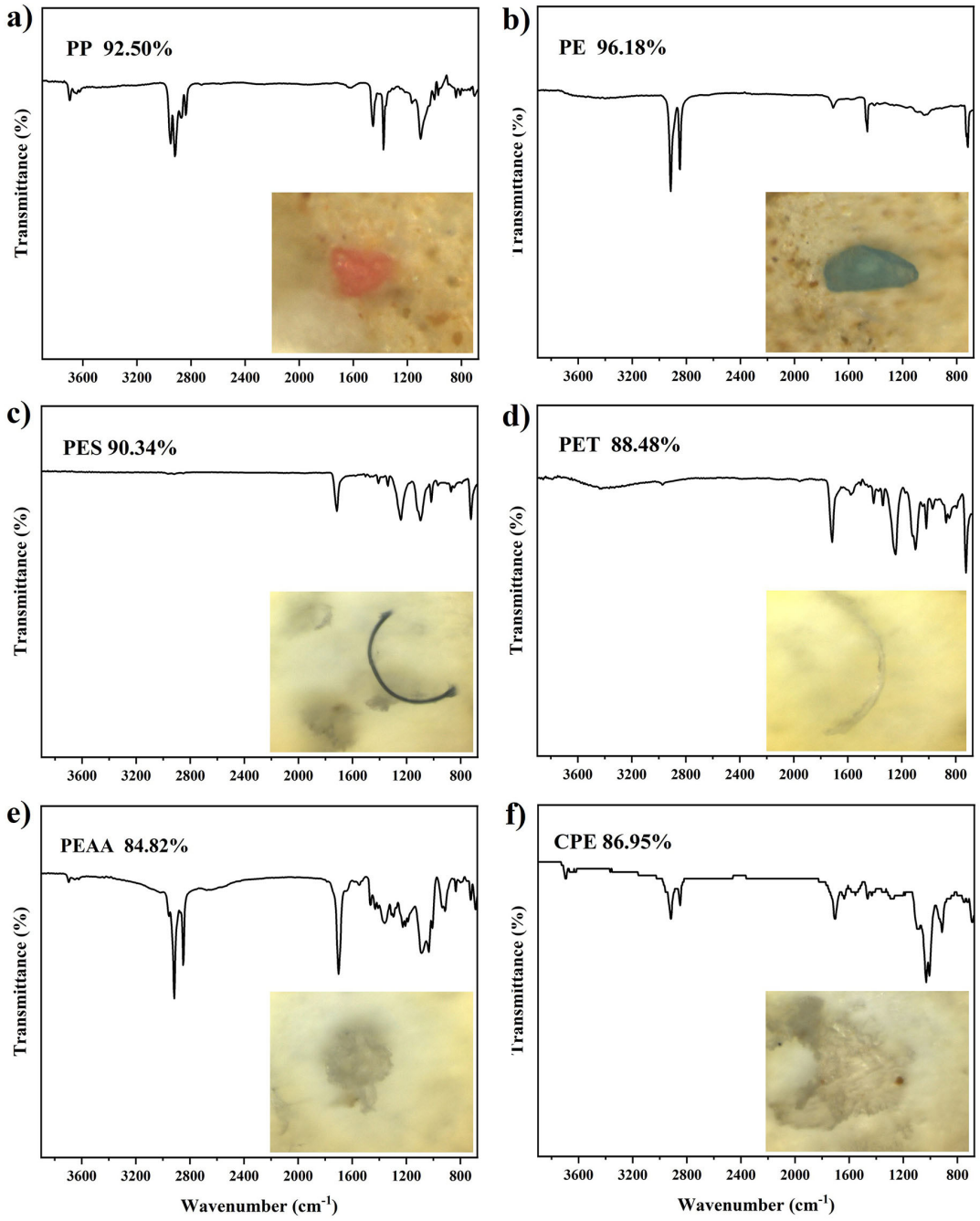

Figure 4. Representative microplastic particles and corresponding FTIR spectra used for polymer identification, with spectral matching percentages: (a) PP (polypropylene), (b) PE (polyethylene), (c) PES (polyester), (d) PET (polyethylene terephthalate), (e) PEAA [poly(ethylene-co-acrylic acid)], and (f) CPE (chlorinated polyethylene)

specific sources to the particles detected in the present study. The relatively higher contribution of PET at NK, particularly in oyster and sediment samples, may partly reflect differences in polymer properties and local environmental conditions. However, interpret this pattern cautiously because polymer identification was performed on a subset of recovered particles. PET has a density greater than that of seawater (approximately 1.38 g/cm^3), which may favor its occurrence in near-bottom water layers and sediments.

Nevertheless, particle size and shape, biofouling, aggregation, and hydrodynamic conditions also influence the environmental behavior of microplastics (Kooi et al., 2017; Zhang, 2017). The presence of PET in both oyster and sediment samples at NK indicates that it occurs across multiple environmental compartments. Although

high-density polymers such as PET tend to accumulate in sediments, sediment transport and bottom shear stress can remobilize them when they cause resuspension (Chen et al., 2026). Such resuspension may increase the availability of previously deposited particles in the water column and represent a pathway for repeated exposure of filter-feeding bivalves to sediment-associated microplastics (Martin et al., 2017). This process may be particularly relevant at NK, where more dynamic coastal circulation could periodically resuspend surface sediments.

Estimated dietary exposure to microplastics through oyster consumption

Under the primary exposure scenario based on the mean ingestion rate of 0.63 g/person/day for Thai young adults aged 18.0–34.9 years, the EAI was 888 particles/person/year at NK and 1009 particles/person/year at LW, with an overall mean of 949 particles/person/year. Under the high-consumption scenario (IR = 6.60 g/person/day), the corresponding EAI increased to 9299 particles/person/year at NK and 10576 particles/person/year at LW, with an overall estimate of 9937 particles/person/year.

The mean-scenario EAI in the present study falls within the broad range reported for oyster-consuming populations in other regions (Table 2). The overall estimate of 949 particles/person/year was higher than the global estimate of approximately 751 particles/person/year reported by Ding et al. (2022). Lower values have been reported in South Korea and several coastal areas of Thailand, whereas higher estimates have been documented in Vietnam, Ghana, and parts of the Mediterranean region (Chinfak et al., 2024; Cho et al., 2019; Doan et al., 2023; Expósito et al., 2022). However, such comparisons should be interpreted cautiously, because exposure estimates depend not only on microplastic abundance and the consumption rates applied but also on methodological differences among studies, including the lower size limit of detection, tissue digestion protocols, and polymer identification techniques.

The EAI values represent potential dietary exposure and should not be interpreted as a direct quantitative assessment of human health risk. Toxicity and toxicokinetic data remain insufficient for human risk assessment of microplastics (EFSA Panel on Contaminants in the Food Chain [CONTAM], 2016), and the available evidence is of only very limited use for assessing risks to human health (World Health Organization [WHO], 2022). Several limitations associated with the consumption-rate assumptions should also be acknowledged. The primary ingestion rate is a per-capita mean that includes both consumers and non-consumers and may therefore underestimate exposure among regular oyster consumers. The approximately tenfold higher EAI obtained using the 97.5th-percentile ingestion rate illustrates the sensitivity of exposure estimates to these assumptions; therefore, population-average and high-consumption scenarios should be distinguished when interpreting dietary exposure. The consumption data covered only a single age group. They were derived from a national survey, which may not reflect consumption patterns in local coastal communities, where oyster consumption may be higher. Future studies should incorporate consumer-specific, locally derived consumption data and seasonal variation in microplastic contamination to improve the representativeness of exposure estimates.

Study limitations

This study was based on a single sampling campaign conducted over two consecutive days during the dry season. Therefore, the observed spatial patterns reflect conditions during the sampling period and may not capture temporal or seasonal variability associated with rainfall, freshwater discharge, tidal conditions, or changes in anthropogenic inputs. The limited temporal and spatial replication also restricted the assessment of associations between environmental parameters and microplastic abundance, preventing the independent evaluation of individual environmental factors. Polymer identification by μ-FTIR was performed on a randomly selected subset rather than on all recovered particles. Consequently, the reported polymer proportions represent the μ-FTIR-analyzed fraction and may not fully capture the polymer diversity and relative composition of all particles recovered from each matrix. Future studies incorporating multi-season sampling, greater spatial replication across broader environmental gradients, and more extensive polymer identification would improve temporal representativeness and allow a more robust assessment of the relationships between environmental conditions and microplastic distribution.

Table 2. Summary of literature reporting the contamination of microplastics in oysters from markets, farms, and wild environments in various regions worldwide

Sampling location	Sampling area	Species	Microplastic abundance		Dominant size	Dominant shape	EAI	References
			(particles/g w.w.)	(particles/individual)	(μm)		(particles/ person/year)	
Market	South Korea	*C.gigas*	0.07 ± 0.06	0.77 ± 0.74	<300	Fragment	521	(Cho et al., 2019)
Farm	Coastline of China	*Crassostrea* sp.	6.64 ± 6.95	NA	20–50	Fragment	≈ 781	(Lin et al., 2024)
	Danang Bay of Vietnam	*C.gigas*	1.88 ± 1.58	18.54 ± 10.08	<100	Fragment	-	(Do et al., 2022)
	Bandon Bay, Gulf of Thailand	*S.commercialis*	1.42	NA	500–1000	Fiber	-	(Ruangpanupan et al., 2023)
	Viet Nam	*C.gigas*	1.24 ± 0.26	8.20 ± 0.45	300–1000	Fiber	2218	(Doan et al., 2023)
	Central and southern regions, Thailand	*S.cucullate*	≈ 0.75–2.30	3.00–7.00	100–500	Fiber	≈ 37–526	(Chinfak et al., 2024)
	Intertidal zone of northern Taiwan	*C.angulata*	0.70 ± 0.40	NA	<200	Fiber	-	(Chen et al., 2023)
	Lima estuary, northwest Portugal	*C.gigas*	0.48 ± 0.34	9.80 ± 7.50	500–2000	Fiber	-	(Moura et al., 2025)
	Amazonian estuaries, Brazil	*C.gasar*	0.23 ± 0.15	1.90 ± 0.70	100–500	Fiber	-	(Pantoja et al., 2024)
	Niantic Bay, USA	*C.virginica*	0.21 ± 0.36	0–2	43–306	Fragment	-	(Mladinich et al., 2024)
	Shandong province, China	*C.gigas*	0.03-0.29	NA	<100	Fragment	-	(Liang et al., 2026)
Wild	Mississippi Gulf Coast, USA	*C.virginica*	4.70 ± 0.25 to 30.70 ± 11.50	NA	30–90	NA	-	(Wontor et al., 2023)
	Gulf of Mexico	*C.virginica*	1.22 ± 0.31 to 4.73 ± 1.08	NA	<1000	Fragment	-	(Austria-Ortíz et al., 2026)
	Rayong province, Thailand	*Saccostrea* sp.	4.13 ± 2.55	9.28 ± 2.97	<250	Fragment	949	This study
	Taiwan coastlines	*Crassostrea* sp. *and Saccostrea* sp.	3.24 ± 1.02	NA	100	Fragment	-	(Liao et al., 2021)
	Mediterranean basin	*O.edulis*	1.98 ± 0.89	2.60 ± 1.32 to 5.88 ± 1.68	<100	Fragment, Fiber	-	(Papini and Rakaj, 2025)
	Viet Nam	*C.gigas*	1.18 ± 0.59	11.55 ± 4.83	<100	Fragment	≈ 3033	(Thao Le et al., 2024)
	Sri Lanka	*S.cucullata*	1.23 ± 0.12	NA	NA	Fiber	-	(Guruge et al., 2024)
	Paranaguá Estuarine Complex, Brazil	*Crassostrea* sp. *and Saccostrea* sp.	1.06 ± 1.28	8.16 ± 6.39	246 ± 296	Fiber	-	(Oliveira et al., 2024)
	Long Island Sound, USA	*C.virginica*	0.59 ± 0.90	2.40 ± 3.36	NA	Fiber	-	(Mladinich et al., 2023)
	Maowei Sea, China	NA	0.42 ± 0.09 to 2.44 ± 0.41	NA	1000–5000	Fiber	-	(Zhu et al., 2021)
	Gulf of Guinea, Ghana	*C. tulipa*	0.34–1.70	1.40–3.40	100–500	Fiber	2600	(Addo et al., 2022)
	North-West Mediterranean Sea, Spain	*C.gigas*	NA	22.8 ± 14.4	<1000	Fiber	8103	(Expósito et al., 2022)
	Northern shores, the United Arab Emirates	NA	0.36 ± 0.24	NA	1000–2000	Fiber	-	(Al Hammadi et al., 2022)

Note: NA: Not available; data not provided in the cited article.

CONCLUSIONS

This study provides an integrated assessment of microplastic contamination in wild oysters, surface water, and sediment from two contrasting coastal and estuarine environments in Rayong Province, Thailand: a marine site (NK) and a freshwater-influenced site (LW). The simultaneous assessment of these environmental and biological matrices revealed differing spatial patterns of microplastic contamination, with significantly higher abundances in surface water and sediment at LW than at NK, while no corresponding difference was observed in oyster tissues. These

findings suggest that spatial differences in environmental microplastic abundance may not be directly reflected in oysters, highlighting the value of assessing multiple environmental compartments when evaluating coastal microplastic contamination. The predominance of small particles, fragments, and fibers, together with the occurrence of several synthetic polymer types, further illustrates the heterogeneous nature of microplastic contamination in the study area. Oyster consumption was identified as a potential dietary pathway for microplastic exposure; however, the estimated annual intake represents potential dietary exposure rather than a quantitative measure of human health risk. Overall, the study provides site-specific evidence that microplastic distribution differs among environmental compartments and edible biota in coastal environments.

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