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Article

Characterization and Ecological Risk Assessment of Microplastics in Sediments of a Tropical West African Lagoon Ecosystem

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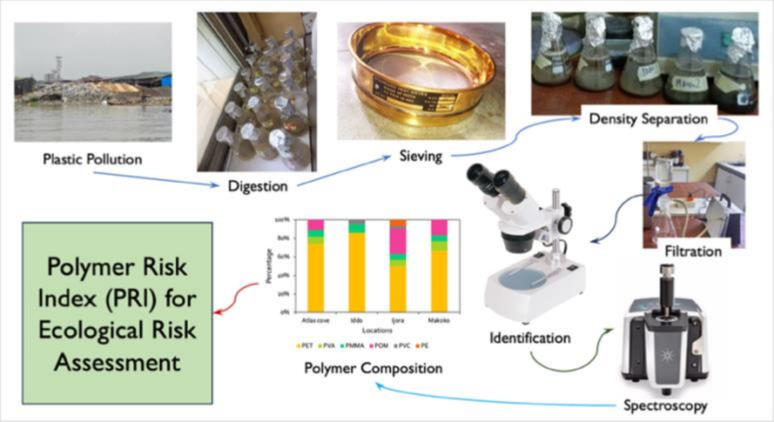
Graphical abstract



Highlights

- Fibers were the most common microplastic type, with black microplastics as the most dominant of the nine colors identified.
- Polyethylene terephthalate (PET) was the most abundant polymer, likely from indiscriminate disposal of single-use plastic bottles.
- The predominance of Level IV and V risk category as indicated by Pollution Risk Index (PRI) depicts high risk level, with significant ecological and environmental implications.

Abstract

The accumulation of mismanaged plastics has continued as a significant threat to the health and ecological functions of coastal ecosystems globally. This study examined microplastic (MP) contamination and ecological risks of twenty-four sediment samples from four locations characterized by significant anthropogenic activities along the Lagos Lagoon. Physicochemical properties of sediment were analyzed using standard methods, while morphological classification of microplastics and polymer identification was carried out using a stereomicroscope and Attenuated Total Reflectance Fourier Transform Infrared Spectroscopy (ATR-FTIR) following pretreatment with 30% H_2O_2 and density flotation with $ZnCl_2$. Microplastic abundance ranged from 9.17 ± 6.05 to 12.17 ± 7.55 microplastics/kilogram (MPs/kg), while morphological analysis revealed predominance of fibers (41.4%) and black microplastics (49%). Polyethylene terephthalate (PET) was the most abundant polymer in sediments, suggesting indiscriminate disposal of single-use plastic bottles. One-way ANOVA showed no significant differences among sampling locations for pH ($F_{3, 16} = 1.29$, $p = 0.31$), electrical conductivity ($F_{3, 16} = 1.10$, $p = 0.37$), total organic carbon ($F_{3, 16} = 1.10$, $p = 0.37$), or microplastic abundance ($F_{3, 16} = 0.31$, $p = 0.82$), suggesting relatively uniform sediment conditions. The detection of potentially toxic polymers raises concern over long-term ecological risks. The Polymer Risk Index (PRI) indicates varying ecological risk, with level IV (high) and V (very high) as the predominant categories. This suggests the potential for significant adverse effects to aquatic organisms and ecosystem health. The result emphasizes the urgent need for improved

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waste management practices, stricter regulation of single-use plastics, sustained monitoring and effective mitigation strategies around the Lagoon's catchments.

Keywords: Microplastics; Sediment contamination; Anthropogenic activity; Fourier transform infrared spectroscopy (FTIR); Ecological risk assessment.

1 Introduction

The global production of polymers, which rose from 200 million metric tons in year 2000 to over 400 million metric tons in 2019, is projected to reach 270 million metric tons annually by 2060 (Franz et al., 2024). However, this growth presents significant environmental challenges, particularly, waste management and ecological contamination, as non-biodegradable plastic wastes tend to accumulate and predominate in aquatic environments (Chae and An, 2018; Jain et al., 2020). Since the latter part of the 20th century, plastics have become a defining feature of both land and water environments, contributing notably to alterations in the Earth's ecological and geological systems (Porta, 2021). The widespread integration of plastics into modern life has resulted in the characterization of the current era as the "Plastic Age Anthropocene". In aquatic environments, plastic contamination typically originates from both primary and secondary sources. Earlier reports indicates that, microplastics (MP) result from the gradual fragmentation of the more abundant primary-sourced plastic polymers (Wang et al., 2019; Fred-Ahmadu et al., 2020; Xu et al., 2020). Primary microplastics are deliberately produced for use in consumer goods such as microbeads in personal care products, feedstock pellets, and plastic films (Xu et al., 2020). In contrast, secondary microplastics are formed through the degradation of larger plastic items already present in the environment. These fragments, typically less than 5 mm in size, are now recognized as the dominant contributors to microplastic pollution, posing significant ecological and human health risks (Wang et al., 2019; Fred-Ahmadu et al., 2020; Xu et al., 2020).

The most common microplastic polymers found in the marine environment include low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET), polyvinyl chloride (PVC), nylon, acrylic, polyurethanes, and biodegradable plastics (Bratovcic, 2019). Polymer type, size, density, shape, exposure routes, and pollutant adsorption have been shown to influence the impacts and risks of microplastic exposure on marine species (Derraik, 2002; Moore, 2008). The increased surface area provided by the small size of microplastics and potential to interact, by serving as vectors of other emerging pollutants, is particularly concerning (Anagnosti et al., 2021). The color of microplastics is also reported to influence their likelihood of being ingested by organisms. Laurier and Mason (2007) noted that microplastics resembling the colors of biological foods are more likely to be consumed by organisms. Chen et al. (2020) also reported that microplastics of varying colors can impact the growth and development of *Scenedesmus obliquus*, a eukaryotic unicellular green alga, and the feeding ability of the crustacean *Daphnia magna*. Additionally, the variety of shapes significantly affect their bioaccumulation and toxicity in organisms (Coverton et al., 2019).

Bioavailability, chemical toxicity, and biofilm formation further exacerbate threats posed by plastics to ecosystem health and ecological receptors (Wright et al., 2013; Chaukura et al., 2021). Toxic additives in plastics, such as flame retardants and heavy metals, can lead to severe ecological effects, including disruptions in development and reproduction of an organism (Rochman et al., 2015). Furthermore, leached plastic additives can enter the food chain, causing reproductive and physiological harm (Luo et al., 2022; Razaviarani et al., 2024). Invertebrates, fish, and birds, particularly those with small sizes, are especially vulnerable to microplastic ingestion, leading to reduced feeding efficiency and internal damage (Boerger et al., 2010; Lei et al., 2018). Adverse effects include gastrointestinal disorders, impaired reproduction, and mortality (Agbekpornu and Kevudo, 2023). Excess microplastics in aquatic ecosystems can also screen out sunlight, thereby reducing chlorophyll content and altering photosynthetic activity (Zhang et al., 2017; Mao et al., 2018; Prata et al., 2019).

Lagoons and coastal areas are designated hotspots and sinks for microplastic pollution globally because of their distinct hydrodynamics, dense populations, and elevated human activities (Garces-Ordonez, 2022). Gündoğdu et al. (2025) revealed an accumulated 15,526 MPs in coastal lagoons of the northeastern Mediterranean region of Türkiye. Peak concentrations of 62.68 ± 12.76 MP/L and 85.25 ± 27.96 MP/kg were recorded in water and sediment at Yelkoma and Akyatan lagoon respectively, with a preponderance of fibrous materials. Celis-Hernandez et al. (2023) revealed concentrations of MPs in Laguna de Terminos in the Gulf of Guinea were 210,000 and 11.3 times higher in water and sediment when compared to other protected sites across the globe. Urbanization and fishing activities were the primary source of dominant polyethylene (Celis-Hernandez et al., 2023; Gündoğdu et al., 2025). The persistence of MPs results in accumulation of significant amounts in sediments (Niu et al., 2023). This increases the need for assessing MPs' ecological risk using common indicators such as pollution load index (PLI), polymer risk index (PRI), and potential ecological risk index (PERI) for pollution mitigation (Yin 2023). For instance, Xu et al. (2018) utilized hazard scores for plastic polymers proposed by Lithner et al. (2011) to create an index for microplastic polymer types, along with the PLI suggested by Tomlinson et al. (1980). In a related study, the ecological risk index by Hakanson (1980) was applied by Peng et al. (2018) to assess microplastics in freshwater river sediments in Shanghai, China, and quantitatively evaluated the pollution risks of microplastics at each sampling sites.

Despite the growing concerns about microplastics pollution globally, relatively few research have been targeted at addressing the extent of contamination in Nigerian coastal waters (Abiodun et al., 2019; Enyoh et al., 2019; Ilechukwu et al., 2019; Olarinmoye et al., 2020; Adeogun et al., 2020; Yahaya et al., 2024; Anyaegbu et al., 2024). Recently, Idowu et al. (2024b) documented high concentrations of microplastics in the Osun River. Similarly, Yahaya et al. (2022) reported significant accumulations of microplastics in sediments from the Badagry lagoon. Despite the alarming concentrations and ecological risks of microplastics reported in these ecosystems, there remains a paucity of comprehensive scientific data on MPs in the sediments of the Lagos Lagoon. Given the Lagos Lagoon's vital role in supporting the nutritional needs of the city's large population, it is important to investigate the abundance, composition, polymer types and potential ecological risks of microplastics in sediments from highly impacted locations within the lagoon. The study hypothesizes that the sediment of the Lagos Lagoon may contain significant amounts of microplastics because of increasing discharges from its catchment, fishing activities, and plastic waste delivery to the shores of the lagoon.

2 Methodology

2.1 Description of the study site

The Lagos Lagoon (6°24'–6°36'N, 3°20'–3°50'W), covering an area of 208 km², is the largest lagoon on the West African coast and the fourth largest in the Gulf of Guinea (Lawson, 2011). It stretches 50 km in length and varies in width from 3 to 13 km, with an average depth of 1.5 m, extending across 6,354.7 km². The lagoon is separated from the Gulf of Guinea by a 2–6 km wide beach (Badejo et al., 2014). It is bordered to the north by the Ogun River and creeks, to the east by the Lekki and Epe Lagoons, and to the south by Five Cowries and Badagry town. Connected to the Atlantic Ocean via Lagos Harbor, the lagoon receives freshwater input from the Ogun and Osun rivers, with temperature ranges from 30°C to 38°C (Ojeh et al., 2016). Seasonal flooding, driven by rainfall, transports debris and pollutants into the Lagoon, making it a critical drainage zone for industrial and domestic runoff from Lagos metropolis (Lawson, 2011).

Designated sampling locations, Atlas cove, Iddo, Ijora, and Makoko (**Fig. 1**), were chosen for the study based on varying environmental conditions and degrees of human impact. The exact locations and coordinates of each of the sampling site representing different land use characteristics were recorded using the Global Positioning System (GPS) as shown in **Table 1**.

2.2 Sampling and sample treatment

A total of 24 surface sediment samples were collected from four locations between December 2021 and December 2023 to reflect the prevailing hydrological conditions of the study area. Six representative samples were taken from each of the four locations, Makoko, Iddo, Ijora, and Atlas cove, during each sampling regime. The surface sediment was collected at the locations using a Van-Veen grab deployed from the edge of an outboard-engine boat (Olarinmoye et al., 2020). The collected samples were separately wrapped in aluminum foil, placed in pre-labeled Ziploc bags, and stored in an icepack at 4°C before being transported to the Environmental Chemistry laboratory, Department of Chemistry, University of Lagos for further

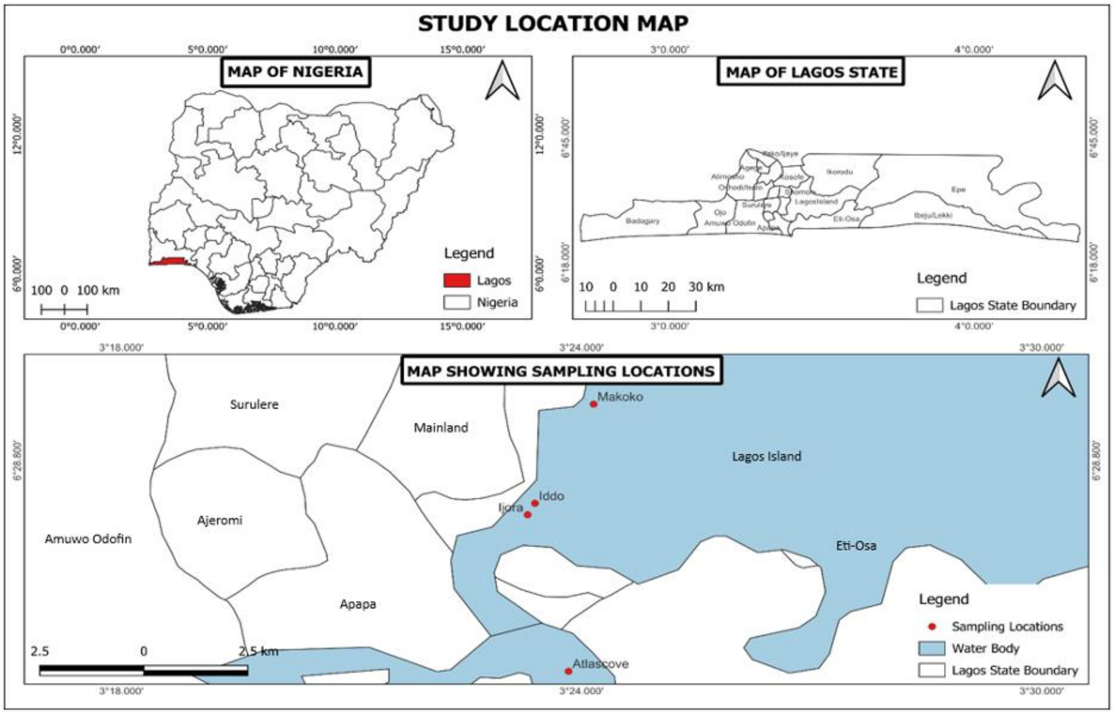

Figure 1. Map of the Lagos lagoon showing the sampling locations.

Table 1. *Coordinates of sampling sites and observed anthropogenic activities in the Lagos Lagoon.*

Locations	Latitude	Longitude	Observed activities
Makoko	6° 29' 37.3194"N	3° 23' 49.4514"E	Fishing, slum settlement, wood logging and canoe used for transportation.
Iddo	6° 28' 39.216"N	3° 23' 26.0154"E	Dump site, open defecation, cement bag washing and local market.
Ijora	6° 27' 51.084"N	3° 22' 31.4034"E	Informal housing area, domestic and industrial effluent discharge.
Atlas cove	6° 25' 47.1"N	3° 23' 57.948"E	Oil and grease, petroleum products depot and canoe used for transportation.

processing. In the laboratory, the sediment samples were placed in ceramic bowls and left to air dry at room temperature. The samples were then sieved to remove large debris, after which they were homogenized for analysis.

2.3 Determination of physiochemical parameters of the sediment sample

5 g sediment sample was mixed with 10 mL of distilled water in a 50 mL beaker and continuously stirred with a glass rod for the determination of pH and electrical conductivity (EC). The pH and EC were measured using electrometric methods with a calibrated Axiom PHS-25 pH meter (using buffers of pH 4.0, 7.0, and 10.0) and DDS-307 conductivity meter (using a 0.1M KCl solution), following the procedures outlined in the U.S. Environmental Protection Agency's Method 9045D (EPA, 2004) and Method 9050A (EPA, 1998), respectively, by immersing the probes into the solutions followed by recording. Total organic carbon (TOC) concentration in sediment was determined using the Walkley-Black chromic acid wet oxidation method (Walkley and Black, 1934). 1.0 g oven-dried sediment sample was placed in a 500 mL Erlenmeyer flask, followed by the addition of 10 mL of 0.167 M $K_2Cr_2O_7$. After gently swirling, 20 mL of concentrated H_2SO_4 was added, and the mixture was further swirled for one minute. The sample was left to stand in a fume hood for thirty minutes, after which 100 mL water and 3-4 drops of ferroin indicator were added to it and then titrated with 0.5 M $FeSO_4$ solution. The endpoint of the titration was marked by a color change from greenish to red (maroon). The TOC was then calculated from the titre value obtained. Total Organic Matter (TOM) was estimated by multiplying the concentrations of TOC by a factor of 1.72 (De Vos et al., 2007).

2.4 Microplastic extraction from sediment samples

Microplastic extraction from surface sediment was carried out following the protocol of Saha et al. (2021), with slight modifications. A 10 g part of the air-dried, homogenized sediment sample was passed through a 5 mm mesh sieve to remove larger plant debris. The sieved sediment was then mixed with 100 mL of 30% H_2O_2 in a glass beaker, stirred continuously, and left undisturbed for 48 hours to remove any biofilms present. After, the sediment was filtered through a 300 μm nylon sieve. The retained microplastics as well as the residual filtered sediment sample were then added to a zinc chloride solution (density: 1.58 g/cm^3) and allowed to settle for 48 hours. The supernatant was thereafter vacuum filtered through 0.45 μm membrane filter. The filter was then stored in a glass Petri dish and oven-dried at 40°C before further analysis.

2.5 Microplastic identification and quantification

The morphological characteristics of the residue on the dried membrane filter were examined and recorded using a stereomicroscope (Bestscope BS-3010A). Observed microplastic shapes were classified into four types: fibers (thin or fibrous, straight plastic), pellets/beads (hard, rounded microplastics), fragments (hard, jagged plastic microplastics), and films (thin, flimsy plastic sheets), as described by Radhakrishna et al. (2021). The filter papers were stored at room temperature and a subset of visually identified was subjected to further characterization using an Agilent Cary 630 Attenuated Total Reflectance Fourier Transform Infrared Spectrophotometer (ATR-FTIR) to identify the predominant microplastic polymers in the sediment samples. The ATR-FTIR, equipped with a single-bounce diamond crystal and a deuterated triglycine sulfate detector, measured spectra of the sediment samples in the mid-infrared (MIR) range from 600 to 1000 cm^{-1}. Each spectrum was recorded over 32 scans in transmittance mode, and the average values were noted. The transmittance spectra were plotted on the y-axis against the wave number on the x-axis and compared with library spectra to identify the polymers.

2.6 Quality control and quality assurance

Plastic instruments were avoided throughout the sampling and analytical procedures to prevent cross contamination. The homogenized samples were stored in wide-mouth glass bottles. Stainless steel spatula was used to dispense the sample as needed for analytical determination. All glassware was thoroughly rinsed with distilled and de-ionized water before use, and lab coats made of non-polymer material was worn during the experiments. The entire process was conducted in a sterile environment, with membrane filters stored in clean glass petri dishes to minimize air exposure. Glass lids were used during microscopic work to further reduce the risk of contamination.

2.7 Ecological risks of microplastics in sediment

The potential ecological risks of microplastics in sediment were evaluated using the Polymer Risk Index (PRI), as outlined by Xu et al. (2018). The PRI is derived from the polymer hazard score, which factors in the environmental persistence, bioaccumulation potential, and toxicity of various polymers, as summarized in **Table 2**. The PRI is calculated using the following equation:

$$\text{Polymer Risk Index (PRI)} = \sum \text{PPT} \times \text{PS}$$

Where PPT is the percent of polymer types collected at each sampling sites, and PS is the polymer score.

Unlike basic particle counts, the PRI incorporates the intrinsic hazard level of different polymers. For instance, polyvinyl chloride (PVC) and polystyrene (PS) carry much higher toxicity scores due to the release of harmful additives and monomers, whereas polymers like polypropylene (PP) are relatively benign (Lithner et al., 2011). PRI allows the identification of high-risk zones where toxic polymers accumulate, by weighting the composition of microplastics. This has been particularly useful in large-scale assessments such as in Mexico (Dueñas-Moreno et al., 2024) and India (Ranjani et al., 2021), where coastal and estuarine sediments showed elevated PRI values due to urban runoff and plastic waste input. Several studies have used PRI to project future risk levels under different plastic pollution scenarios. For example, Japan's coastal PRI is expected to rise significantly by 2060 if current plastic consumption trends continue (Nakano et al., 2023). This highlights PRI's usefulness for trend forecasting and strategic planning.

3 Results and discussion

3.1 Physicochemical characteristics of sediment sample

The pH levels of the sediment samples ranged from slightly acidic to alkaline, with the highest mean pH of 8.97 recorded at Iddo and the lowest mean pH of 6.83 at Ijora. The mean pH values for the sediments ranged from 7.08 ± 1.27 at Atlas cove, 8.97 ± 3.01 at Iddo, 6.83 ± 1.74 at Ijora, and 7.37 ± 1.93 at Makoko. The observed pH levels are consistent with the range reported in a recent study by Echebiri et al. (2023) for the Lagos Lagoon.

Generally, the mean EC values of the sediments varied across the four sampling locations with highest mean values of 5.66 ± 5.15 mS/cm recorded in sediments from Ijora and the lowest mean values of 1.86 ± 1.73 mS/cm recorded in Atlas cove. Relatively higher mean EC of 4.84 ± 4.98 mS/cm were also recorded in sediments from Iddo when compared to a mean EC of 3.55 ± 2.35 mS/cm in sediments from Makoko segment of the Lagoon.

TOM levels varied across the different sampling locations. Atlas cove recorded the lowest average TOM concentration of 1.47 ± 2.43%. In comparison, Iddo and Ijora exhibited relatively higher average TOM levels of 2.57 ± 2.60% and 3.36 ± 2.93%, respectively. However, Makoko recorded the highest TOM concentration, with an average of 4.29 ± 3.47%. The elevated TOM levels at Makoko are likely influenced by the predominant logging and sawmill activities, as well as human waste discharges, whereas the lower TOM levels at Atlas cove are likely attributed to its location near an isolated, unpopulated jetty with petroleum product receiving and storage facilities.

TOM often enhances microplastic retention in sediment by promoting aggregation and microbial interaction, particularly in sediments of vegetated and coastal ecosystems (Peng and Yang, 2022). Corcoran et al. (2019) in a study on Thames River,

Table 2. *Hazard scores of various polymer types, and associated risk categories based on polymer abundances adapted from the literature.*

Polymer type	Hazard score	Reference	Polymer abundance (MPs/Kg)	Risk category
Polypropylene (PP)	1	Lithner et al. (2011)	1–10	I (Very low)
Polyethylene terephthalate (PET)	4	Lithner et al. (2011)	10–100	II (Low)
Polyethylene (PE)	11	Lithner et al. (2011)	100–1,000	III (Moderate)
Polyvinyl alcohol (PVA)	36	Yahaya et al. (2022)	1,000–10,000	IV (High)
Polymethyl methacrylate (PMMA)	1,021	Lithner et al. (2011)	>10,000	V (Very high)
Polyoxymethylene (POM)	1,500	Lithner et al. (2011)	Source: Yuan et al. (2022)	
Polyvinyl chloride (PVC)	10,001	Lithner et al. (2011)		

Canada, found that the highest microplastics levels occurred in fine grained sediments with high organic debris thus showing that organic rich matrices enhance MPs retention due to aggregation and reduced hydrodynamic energy. Li et al. (2022) also showed that increased MPs burial (x1.7) in blue carbon ecosystems like mangroves and saltmarshes could be facilitated by vegetation-mediated sedimentation and organic matter accumulation.

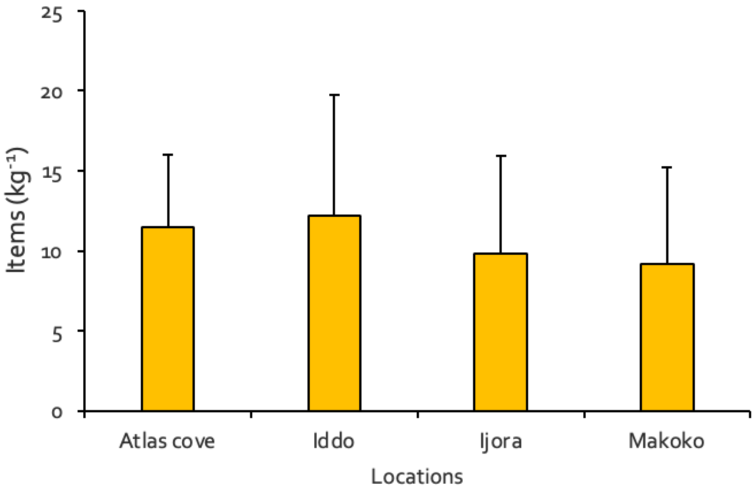

Figure 2. *Mean (and standard deviation) abundance of microplastics (items) in sediments across different sampling locations within the Lagos Lagoon.*

The TOM values recorded in this study, ranging from 1.47% to 4.29%, is lower than 7.72% which was reported in Ozomu Lake, Edo State, Nigeria (Olomukoro and Enabulele, 2024), potentially due to runoff from the Lagoon's tributaries. The elevated TOM levels indicate a water system with heightened productivity and evident signs of eutrophication. The increasing nutrient enrichment within the Lagoon is likely driving eutrophication across extensive areas, particularly in regions adjacent to Ijora, Iddo, and Makoko.

Hydrodynamic conditions significantly impact TOC distribution by controlling sediment deposition, resuspension, and particle transport. Areas exposed to strong tidal currents or wave action, such as Atlas cove, often exhibit lower TOC due to the winnowing of fine particles and organic matter. In contrast, sheltered environments like Makoko facilitate the settling of fine-grained, organic-rich sediments, leading to higher TOC concentrations (Chen et al., 2024).

3.2 Microplastics abundance and composition in sediment sample

A total of 256 microplastics were identified in the sediment samples, with the highest abundance observed at Iddo (73), followed by Atlas cove (69), Ijora (59), and Makoko (55). The distribution of microplastics across the locations was in the order: Iddo (29%) > Ijora (27%) > Atlas cove (23%) > Makoko (21%). The highest average concentration of microplastics was recorded at Iddo (12.17 ± 7.55 MPs/kg), followed by Atlas cove (11.50 ± 4.51 MPs/kg), Ijora (9.83 ± 6.11 MPs/kg), and Makoko (9.17 ± 6.05 MPs/kg) (**Fig. 2**).

Seasonal fluctuations observed in microplastic concentrations across sampling sites indicates the influence of local hydrological processes on microplastic distribution. For instance, moderate increase in microplastic abundances from dry season (10.0 ± 5.6 particles) to wet season (13.0 ± 3.6 particles) at Atlas Cove, suggesting a steady contribution from runoff during periods of increased rainfall (**Fig. 3**). In contrast, minimal seasonal divergence was recorded for Iddo, with slightly higher dry season levels (12.7 ± 8.1 particles) compared to the wet season (11.7 ± 8.7 particles), pointing to complex and possibly competing hydrodynamic and depositional processes affecting microplastic retention or transport. Relatively stable concentrations were recorded for Ijora between seasons with a total of 9.7 ± 6.0 particles in the dry season and 10.0 ± 7.5 in the wet season. Notably, Makoko exhibited the most pronounced seasonal shift, with microplastic levels rising sharply from a low dry-season concentrations (6.0 ± 2.6 particles) to approximately double in the wet season (12.3 ± 7.4 particles). This striking contrast points to the influence of rainfall-mediated influxes, possibly exacerbated by urban runoff and proximity to densely populated, flood-prone areas. These findings highlight the dynamic interplay between hydrological

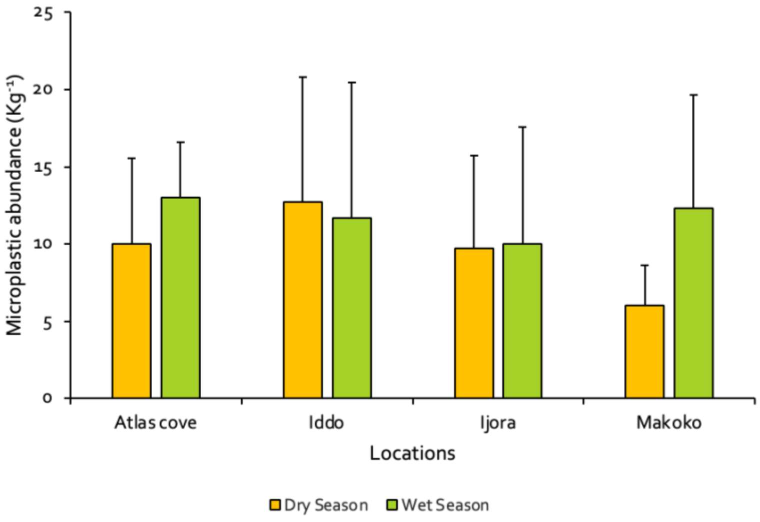

Figure 3. *Seasonal variation in microplastic abundance (mean and standard deviation) in sediments across different sampling locations within the Lagos Lagoon.*

regimes and microplastic loadings, reinforcing the need to integrate watershed characteristics and seasonal patterns into microplastic monitoring and pollution management strategies.

Table 3. *Correlation matrix of microplastic abundance and sediment physicochemical parameters in the Lagos Lagoon.*

Parameters	pH	EC	TOM	Microplastic abundance
pH	1			
EC	-0.07	1		
TOM	-0.21	0.38	1	
Microplastic abundance	-0.12	-0.22	-0.11	1

The abundance of microplastics in this study is relatively lower compared to the findings of Olarinmoye et al. (2020). They reported concentrations ranging from 310 to 2,319 MPs/kg. However, the levels observed here are similar to those reported in the Southern Baltic Sea by Graca et al. (2017), which ranged from 0–27 MPs/kg. In contrast, higher abundances have been reported in Nigeria's freshwater systems (Ololade et al., 2024; Idowu et al., 2024a) and marine ecosystems (Olanipekun et al., 2024; Idowu et al., 2024b). These variations are likely due to differences in mesh sizes, sampling techniques, and data estimation methods, all of which can influence the observed microplastic size and concentration (Graca et al., 2017).

Statistical analysis revealed no significant differences among the groups for any of the variables assessed. The ANOVA results showed an F-statistic of 1.29 ($p = 0.31$) for reported pH levels, indicating that observed variations were not statistically significant. Similarly, EC ($F = 1.10$, $p = 0.37$), TOC ($F = 1.10$, $p = 0.37$), and microplastic counts ($F = 0.31$, $p = 0.82$) all demonstrated no significant differences across the groups. Posthoc-Tukey HSD comparisons revealed no significant pairwise differences, supporting spatial homogeneity of sediment microplastic loads during the six sampling periods. The correlation matrix revealed that microplastic abundance exhibits weak negative correlations with all measured parameters, including pH ($r = -0.12$), EC ($r = -0.22$), and TOM ($r = -0.11$), indicating no strong linear relationship (**Table 3**). Among the variables, the strongest correlation was observed between TOM and EC ($r = 0.38$), suggesting a moderate positive association likely linked to shared geochemical influences. Overall, the results suggest that microplastic abundance in the sampled environment is not strongly influenced by pH, EC, or TOM, implying that its distribution may be governed by physical or anthropogenic factors rather than the sediment's chemical properties.

3.3 Morphometric characterization of microplastics

Morphometric analysis identified three distinct microplastic shapes: fibers, fragments, and films (**Fig. 4**). Fibers were the most prevalent, accounting for 41.4% of the total microplastics, followed by fragments (37.5%) and films (21.1%). At Atlas cove, fragments were the most dominant microplastic shape, accounting for 43% of the total microplastic count, followed by fibers at 35%, and films at 22%. At Iddo, fragments also showed the highest abundance, comprising 55%, followed by fibers at 37%, and films at only 8%. In contrast, Ijora exhibited a different pattern, with fibers being the most abundant shape at 49%, followed by films at 31%, and fragments at 20%. At Makoko, fibers dominated the composition at 47%, while fragments and films were present in similar proportions, at 25% and 27% respectively.

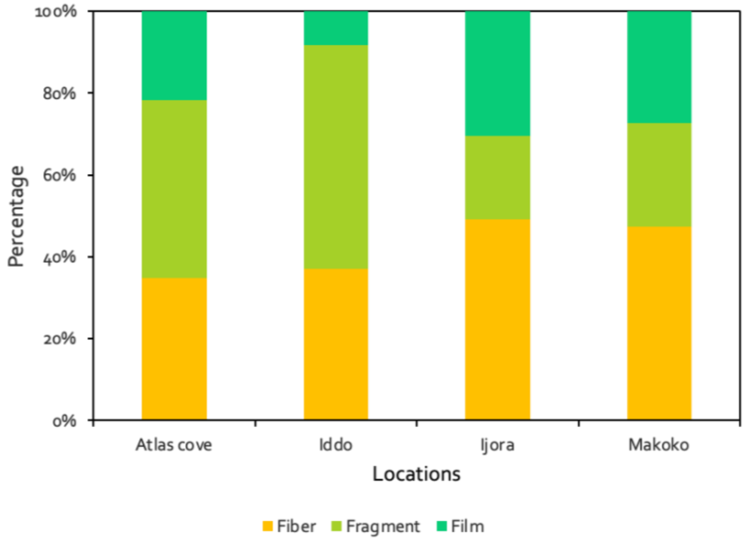

Figure 4. *Morphological composition of microplastics identified in sediments across different sampling locations in the Lagos Lagoon.*

The prevalence of fibers and fragments in the Lagos Lagoon during the present study is consistent with previous studies on microplastic morphology in aquatic environments (Olarinmoye et al., 2020; Zhao et al., 2020; Xia et al., 2021; Yahaya et al., 2022; Dada and Bello, 2023). The dominance of fibers is likely attributed to multiple sources, including oceanic influx, fiber-based waste from laundry activities, erosion, and urban runoff (Olarinmoye et al., 2020). This observation aligns with that of Browne et al. (2011). They reported that a single piece of clothing can shed over 1,900 fibers during washing. Similarly, Abidli et al. (2017) found fibers to be the most abundant microplastic type (88.88%) in the Bizerte Lagoon Channel.

Furthermore, the elevated concentrations of microplastic fragments in Atlas cove and Makoko likely reflect the contributions from polyethylene (PE), commonly referred to as "nylon" and other single-use plastics. These are presumed to originate from vessel-based waste in Atlas cove and domestic discharges from stilted shack houses in Makoko, respectively. Similarly, Fred-Ahmadu et al. (2020) reported fragments as the predominant microplastic shape along the high-waterlines and drift zones of the Atlantic Ocean. However, microplastic forms, such as foam, microbeads, and filaments, were not detected in this study.

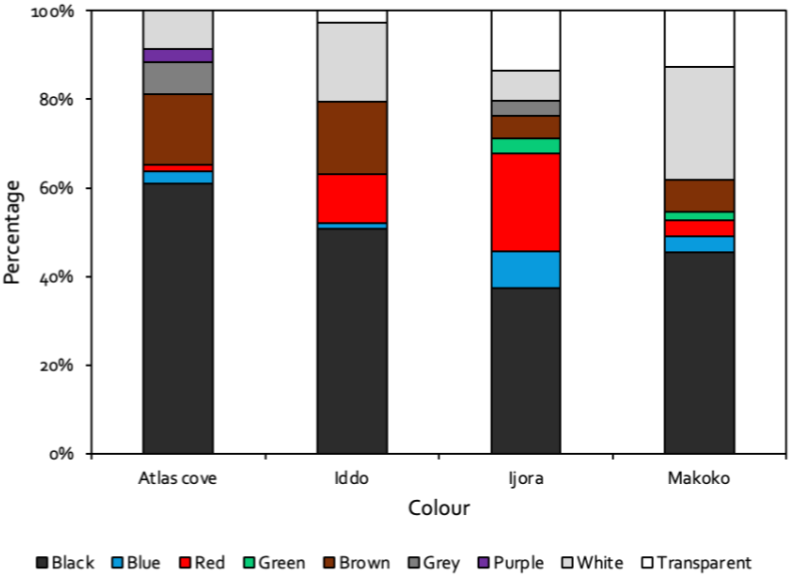

Figure 5. *Colour composition of microplastics identified in sediments across different sampling locations in the Lagos Lagoon.*

3.4 Color distribution of microplastics

Colorimetric analysis revealed nine distinct microplastic colors: black, blue, red, green, brown, grey, purple, white, and transparent (**Fig. 5**). Black microplastics predominated across all sampling sites, ranging from 37.29% to 60.87% at Ijora and Atlas cove, respectively. This finding aligns with the results of Olanipekun et al. (2024) and Idowu et al. (2024a). They reported the predominance of black microplastics in coastal estuarine and Osun River, respectively. Inyang et al. (2024) also found black microplastics (41.7%) in Azuable Creek with primary source from plastic waste, including bottle caps, textile fibers, plastic bags, and twines. High rates of ingestion of black MPs have been reported in filter-feeding and carnivorous polychaetes which strongly correlates with surrounding sediment contamination, feeding behavior and water conditions (Vecchi et al., 2021; Fang et al., 2025).

More diverse microplastic colours (7 distinct) were documented at Atlas cove and Ijora with red representing the lowest (1.4%) and the highest (22.03%) of totals, respectively across all sampling sites (**Fig. 5**). Studies have shown that microplastics, particularly fibers in the black and red color ranges, are frequently found in edible tissues of filter-feeding species like oysters and mussels (Naidu, 2019; Joshi et al., 2024). Microplastic colours were less diverse at Iddo with dominance of black (50.68%), followed by white (17.81%), then brown (16.44%) and red (10.96%). Green microplastics were only present at Ijora and Makoko, recording 3.3% and 1.8% of the total. All sampling sites reported the presence of white microplastics except Atlas cove which recorded distinct purple microplastics (2.9%). The color of microplastics influences their behavior, including adsorption, desorption, degradation of contaminants, and their potential role as vectors for other pollutants (Zhao et al., 2022). This spatial variation in microplastic color composition reflects differences in anthropogenic influences and environmental conditions at each site. Ingested microplastics can act as vector for additives or pollutants like heavy metals and persistent organic pollutants (POPs), which can potentially leach into the tissues of fish and shellfish. When consumed, this might pose potential risks to human health, including endocrine disruption, inflammation or gastrointestinal effects (Bhuyan, 2022). The study on mullet found black-colored fibers in both edible and inedible tissues, confirming the potential for human ingestion through seafood consumption (Gayathry et al., 2023).

3.5 Polymer composition of microplastics

Out of the 256 visually identified microplastics, 108 (42.2%) were subjected to ATR-FTIR analysis for polymer identification. Spectroscopic analysis identified six polymer types in the sediment samples: polyethylene terephthalate (PET), polyvinyl alcohol (PVA), polymethyl methacrylate (PMMA), polyoxymethylene (POM), polyvinyl chloride (PVC) and polyethylene (PE). PET was the most dominant polymer, accounting for 67.6% of the total microplastics (**Fig. 6**). This was followed by POM (14.8%), PMMA (7.4%) and PVA (6.5%). PVC and PE were the least detected, each constituting 1.85% of the total. PET was found in all four locations, with the highest concentration in Atlas cove and Makoko (27.40%), followed by Iddo (24.66%), and the lowest at Ijora (20.55%). PVA was completely absent in Iddo but present in the other three locations. It occurred at 28.57% in both Atlas cove and Ijora and reaches its highest value in Makoko at 42.86%. PMMA shows uniform distribution across all four locations, with each site recording a consistent concentration of 25%. POM was not detected in Iddo, but it is present at 18.75% in Atlas cove, 50% in Ijora and 31.25% in Makoko. PVC was completely absent in Atlas cove and Makoko, but appears at 50% in both Iddo and Ijora, making it a shared dominant polymer in these two locations only. PE was only detected in Ijora at 100% and completely absent in Atlas cove, Iddo and Makoko.

3.6 Ecological risk assessment of polymers

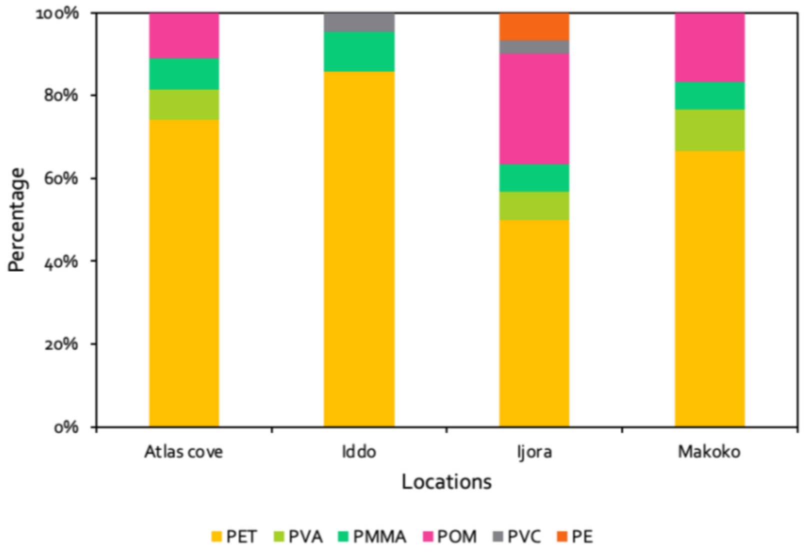

Figure 6. *Polymer composition of microplastics identified in sediments across different sampling locations in the Lagos Lagoon.*

The results of the PRI used in estimating the potential ecological risks associated with microplastics in sediment based on the polymer hazard score are summarized in **Table 4**. The polymers identified in this study has the potential for varying levels of environmental risk across the different sampling locations in Lagos Lagoon. According to the polymer hazard classification, the detected levels of polyoxymethylene (POM), polymethyl methacrylate (PMMA), and polyvinyl alcohol (PVA) in the sediment samples indicates high (Level IV) to very high-risk levels (Level V), suggesting potential for adverse environmental impacts at the impacted sites. Polyethylene terephthalate (PET), widely used in plastic bottle production, was categorized as a moderate-risk polymer (Level III) in samples from Atlas cove and Makoko but a low-risk polymer (Level II) was categorized in Iddo and Ijora. However, its prevalence in all sampled sites suggests a continuous and persistent environmental risk. In contrast, polyethylene (PE) and polyvinyl chloride (PVC) were not detected during the present study in sediment samples from Atlas cove and Makoko, while PE was only detected in Ijora, likely due to localized variations in plastic waste inputs in these areas. The absence of PE and PVC at the Atlas cove sampling site likely reflects the minimal presence of permanent residential settlements in the area. These polymer types are commonly associated with domestic refuse such as disposable carrier bags, packaging films, and household containers, which are more prevalent in stable, residentially dense environments. Similarly, Makoko site, characterized by informal and largely transient settlements associated with wood-processing activities, also exhibited a relatively low abundance of PE and PVC. The plastic debris profile was dominated by polyethylene terephthalate (PET) bottles, suggesting a shift in plastic use and disposal patterns toward beverage-related products, likely due to the occupational and transient nature of the population. These findings highlight the influence of local demographic dynamics, settlement type, and socio-economic behaviors on the composition of plastic debris across different urban waterfronts.

Polymer-specific abundance and hazard scores classified polyethylene (PE) and polyvinyl chloride (PVC) in sediments from Ijora as high-risk (Level IV) and very high-risk (Level V), respectively. The results also indicate a very high-risk level for PVC at Iddo, highlighting its significant ecological threat driven by its persistence and inherent toxicity. The presence of residential settlements in these locations may have contributed to the occurrence of these polymers in sediment samples. The result of the polymer analysis supports the findings of Idowu et al. (2024b), they identified polyethylene terephthalate (PET) as the most frequently detected polymer, followed by other common plastics such as low-density polyethylene, polypropylene, and polystyrene in the sediments of Nigerian coastal estuaries. The prevalence of PET in Lagos Lagoon suggests its widespread use in plastic bottles, which can degrade into mesoplastics and microplastics (Olanipekun et al., 2024). The very high-risk score (Level V) obtained from the risk classification for most of the detected polymers in the present study further emphasize the potential for significant environmental impact these plastic materials may have on aquatic organisms. In contrast, Yahaya et al.

Table 4. *Polymer Risk Index (PRI) categories and associated risk classification levels for microplastics in sediments from the Lagos Lagoon. N.D stands for not detected.*

Polymer type	**Sampling locations**			
	Atlas cove	**Iddo**	**Ijora**	**Makoko**
Polyethylene terephthalate (PET)	III	II	II	III
Polyvinyl alcohol (PVA)	IV	N.D.	IV	IV
Polymethyl methacrylate (PMMA)	V	V	V	V
Polyoxymethylene (POM)	V	N.D.	V	V
Polyvinyl chloride (PVC)	N.D.	V	V	N.D.
Polyethylene (PE)	N.D.	N.D.	IV	N.D.

(2022) reported a predominance of polymer risk Level III in sediment from Badagry Lagoon, while Fred-Ahmadu et al. (2020) observed low-risk polymer levels in water samples from the Atlantic Ocean.

The results highlighted the dominance of black secondary microplastic debris and the prevalence of high-risk polymers in Lagos Lagoon. This contamination is primarily attributed to inadequate waste management practices, particularly the conversion of several shoreline areas into informal dumpsites. Although the overall abundance of microplastics observed in this study was lower than the levels reported in other Nigerian coastal regions (Olarinmoye et al., 2020), the identification of specific polymer types, especially polyethylene terephthalate (PET) raises significant environmental concerns. PET and other high-risk polymers pose persistent threats to aquatic ecosystems due to their durability and potential for chemical leaching. Their presence in the Lagoon signals not only significant anthropogenic pressures but also emerging risks to public health, particularly in communities dependent on these waters for their livelihood. These findings highlighted the urgent need for enhanced regulatory measures on single-use plastics, improved recycling initiatives, and long-term monitoring strategies focused on key microplastic sources, including fishing gear, synthetic fibers from laundry, and urban stormwater runoff. Microplastic pollution, in this context, may pose an increasing threat to the ecological integrity and resilience of Lagos Lagoon.

An evaluation of this study's results compared with published research is provided (**Table 5**). While variations and limitations regarding sampling techniques, site conditions, and analytical methods may exist, the result highlighted consistent trends, particularly, the dominance of polyethylene-based polymers and significant site-specific differences in microplastic abundance and composition. These comparative insights are essential for understanding the unique contamination profile of Lagos Lagoon and highlight the importance of localized, ongoing monitoring efforts as part of the broader regional strategies to assess and mitigate plastic pollution in aquatic environments.

4 Conclusion

The findings from this study indicates the pervasive and diverse nature of plastic waste in Lagos Lagoon, with a notable presence of black fibers and fragments, which can be traced to primary sources of contamination. While the overall abundance of microplastics was relatively low, the findings highlight the need for more comprehensive sampling, identification, and quantification methods to better assess the extent of contamination. The prevalence of polyethylene terephthalate (PET) and other high-risk polymers points to significant environmental concerns, emphasizing the urgent need for improved waste management strategies. Moreover, the study calls for increased public awareness regarding proper plastic waste disposal and the promotion of sustainable recycling practices. Addressing these issues is critical to safeguarding the ecological health of Lagos Lagoon and ensuring the well-being of the surrounding coastal communities.

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6 Data availability statement

The data is presented in the manuscript as figures and tables. The data can be made available upon request from the corresponding author.

7 Author contributions

AIO-A: conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, validation, and writing – original draft. AAA: investigation, methodology, project administration, validation, and writing – review & editing. TAO: investigation, methodology, visualization, writing – original draft, and writing – review & editing. LOC: conceptualization, funding acquisition, resources, supervision, and writing – review & editing. All authors have read and approved the final version of the manuscript.

8 Conflict of interest

The authors declare no conflict of interest related to this study.

9 Ethical statements

This study does not require ethical approval.

10 Copyright statement

Table 5. *Comparison of microplastic abundance and composition in sediments from recent studies.*

Location	**MPs Conc. (MPs/kg)**	**Morphology/ Shapes**	**Color**	**Polymer Type**	**Ecological Risk Assessment**	**Source**
Lagos Lagoon, Nigeria	9.17 ± 6.05 to 12.17 ± 7.55	Fibers, Fragments and Films	Black, White, Red, Blue, Brown, Grey, Transparent, Green and Purple	PET, POM, PMMA, PVA, PVC, PE	PRI: Level IV for POM, PMMA, PVA; Level III for PET; Levels I–II for PE, PVC	*This Study (2025)*
Tuticorin, India	7 ± 2.65 to 19 ± 6	Fragments, Fiber, Foam, and Film	Green, Blue, Red, Black, Transparent	PP, PE, PA, PS	PERI: Medium–High Risk PHI: Category III–V (High to Extreme Danger) PLI: Category I–II (Minor to Moderate Pollution)	Esmeralda et al. (2022)
Liaodong Bay, China	32.33 – 49.91	Fibers	Black, Blue	Rayon, PET, PA, PP, PE	Low (PLI Level I)	Ye et al. (2023)
Gulf of Guinea (Offshore Nigeria)	218–1033	Filaments, Plastic Films, Fiber, and Microbeads	Not stated	PVA, CR	PRI: medium and low risk PERI: high-risk	Yakub et al. (2024)
Limfjord, Denmark	273–4288	Fragments	Not stated	Polyester, PP, PE, PS, PA, PU, PVC, acrylics, and epoxy/phenoxy resins	PLI: low to very high levels	Simon-Sánchez et al. (2024)
Thoothukudi, Tamil Nadu, India	32 ± 26 to 232 ± 229	Fragment (dominant)	Blue (dominant)	Polyethylene (PE) dominant	PHI: Hazard Level V – Severe contamination PLI: Hazard Level I – Lower contamination Risk Index (RI): Higher risk category	Keerthika et al. (2022)
Buriganga River, Bangladesh	3.5–8.17	Fibers and fragments dominant	Blue dominant	PETE, EVA, HDPE, ABS, CA, Nylon	Ecological risk category: Category-I	Haque et al. (2023)
Yangtze River Basin, China	611	Fiber	Transparent, Coloured	PP, PVC and PC	Multiple Deterministic Risk Assessment: - Low pollution load - Moderate-to-low potential ecological risk - High polymer pollution	Yang et al. (2023)
Yamaguchi Prefecture, Japan (Awano, Ayaragi, Asa, and Majime Rivers)	167.29 ± 232.29	Fragments (dominant)	Not stated	PVC, PE, PP, PMMA, PU, FEP, PB and ABS	Risk levels ranged from low to very high	Kabir et al. (2022)
Dhaka, Bangladesh (Buriganga, Turag, and Balu River)	46 – 534	Films, fragments, and fibers	Black, White, Grey, Yellow, Red, Green, Blue, and Transparent.	PP, PVA, PET, PE, PS, Nylon 6, PPS, EP, PVC, ABS, PUR	PLI: >1 (Polluted) ERI: Low to very high PHI: Low to medium	Islam et al. (2023)
Haizhou Bay, China.	2,310 ± 1,350	Fibrous (Dominant)	Blue (Dominant)	PVC (Dominant)	PLI: Risk level II.	Liang et al. (2024)
Tropical backwaters, Kerala, India.	407	Fibers, fragment and filament	Coloured and Transparent	PS, PP, PA, PE	PHI > 1000; Hazard category IV–V. PERI: Extreme ecological risk	Radhakrishnan et al. (2023)
Jinzhou Bay, Dalian, China	1192 (visual analysis), 2361 (LDIR spectroscopy)	Mostly small-sized (<250 µm); 10–250 µm (89.21%), especially 10–50 µm (46.45%)	Not specified	PA, PE, PP, PET, ABS; high-risk: PVC, ABS, PUR	PERI: Extremely high risk (LDIR);	Yu et al. (2024)
Haizhou Bay, China	10.1 ± 12.8	Fibers	Not specified	PA, PET (high hazard)	PHI: Grade II PLI: Level I	Gao et al. (2024)

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