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Microplastic Pollution in Mangrove-Adjacent Coastal Environments and Apparent Polymer Mass Loss in Mangrove Sediment Microcosms: A Case Study from Xiatanwei and Wuyuanwan

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Abstract

Microplastic pollution has emerged as a global environmental concern, with mangrove wetlands serving as both sinks and potential bioremediation sites for plastic debris. This study investigated microplastic contamination in water and sediment samples from Xiatanwei mangrove wetland and Wuyuanwan, China, and further examined the degradation of four types of microplastics—polyethylene (PE), polystyrene (PS), polyamide (PA), and fishing net fragments—in mangrove sediment microcosms over a 6-month incubation period. Across the three sediment zones sampled in Xiatanwei, the mean NaCl-recoverable microplastic abundance was approximately 483 items/kg, which was lower than the mean value of 935 items/kg previously reported for the Jiulong River estuary. Water samples from Wuyuanwan revealed a spatial distribution pattern with the highest abundance at the bay mouth (1661 items/m^3), followed by the outer bay (1297 items/m^3) and the inner bay (1056 items/m^3), suggesting complex hydrodynamic influences on microplastic distribution in semi-enclosed bay systems. The 6-month incubation experiment demonstrated that PS exhibited the highest weight loss (6.02% ± 1.66%), followed by PE (3.07% ± 0.86%), while PA (0.56% ± 0.18%) and fishing net (0.52% ± 0.05%) showed minimal degradation. These findings confirm that mangrove sediments possess intrinsic microplastic-degrading capacity, though the extent varies significantly by polymer type. This study provides empirical evidence supporting the role of mangrove wetlands in microplastic trapping and degradation, with implications for coastal pollution management.

Keywords

Microplastics, Mangrove Wetlands, Polyethylene, Polystyrene, Polyamide, Fishing Net, Degradation, Xiatanwei, Wuyuanwan

1. Introduction

Plastic pollution has become one of the most pressing environmental challenges of the 21st century. Approximately 8 million tons of plastic waste enter the oceans annually through rivers and other pathways [1]. Upon entering marine environments, larger plastic debris undergoes physical, chemical, and biological weathering, fragmenting into microplastics—particles smaller than 5 mm in diameter [2]. China is one of the world's largest producers of plastic waste, contributing substantially to marine microplastic pollution [3].

Microplastics have been detected in marine ecosystems, terrestrial soils, and even atmospheric circulation systems [4]. Their small size and persistence enable them to enter food webs through bioaccumulation, ultimately reaching humans and posing potential health risks, including chronic inflammatory responses and endocrine disruption [5] [6]. The United Nations Environment Programme (UNEP) has identified marine plastic pollution as a global ecological priority alongside ocean acidification and global warming.

Mangrove wetlands, which are highly productive coastal ecosystems, have been recognized as effective traps for microplastics. Their complex root systems and dense vegetation slow water flow, promoting the sedimentation of suspended particles, including microplastics [7]. Furthermore, mangrove sediments are rich in organic matter and microbial communities, creating favorable conditions for pollutant degradation. Recent studies have shown that mangrove sediments can harbor plastic-degrading microorganisms, such as *Pseudomonas* and *Bacillus* species, which may contribute to the biodegradation of microplastics [8] [9].

However, the extent to which different polymer types degrade in mangrove environments remains poorly understood. Most studies have focused on polyethylene (PE) and polypropylene (PP), while polystyrene (PS) and polyamide (PA)—also common in marine environments—have received less attention [10]. Additionally, fishing nets made of nylon (PA) or other synthetic fibers represent a substantial proportion of marine plastic debris (referred to as "ghost gear"), yet their degradation behavior in mangrove settings has rarely been investigated [11].

To address these knowledge gaps, this study had two main objectives: (1) to assess microplastic contamination in water and sediment samples from Xiatanwei mangrove wetland and Wuyuanwan, China, through field surveys; and (2) to evaluate the degradation of four types of microplastics—PE, PS, PA, and fishing net fragments—in mangrove sediment microcosms over a 6-month incubation period. The findings are expected to provide baseline data on microplastic pollution in these coastal areas and to offer experimental evidence for the bioremediation potential of mangrove ecosystems.

2. Materials and Methods

2.1. Field Sampling

2.1.1. Study Sites

Field sampling was conducted at two locations in Fujian Province, China: Xiatan-

wei mangrove wetland and Wuyuanwan. Xiatanwei is a typical mangrove wetland ecosystem with well-developed *Avicennia marina* stands. Wuyuanwan is a semi-enclosed coastal bay surrounded by urban areas, representing an environment heavily influenced by anthropogenic activities.

2.1.2. Sediment and Water Sample Collection

Sediment samples were collected from Xiatanwei at three tidal zones: low-tide mud, high-tide mud, and mangrove sediments. At each tidal zone, three replicate sediment samples (each approximately 200 g) were collected from the upper 0 - 5 cm surface layer using a stainless-steel spatula. The three replicates were collected from within a 10 m × 10 m quadrat, with a minimum spacing of approximately 5 m between replicates, and were treated as independent field samples. The low-tide mud was sampled during the lowest spring tide, while the high-tide mud and mangrove sediments were sampled during emersion periods. All samples were stored in clean glass bottles and transported to the laboratory at 4˚C for further analysis. For water samples, three replicate 10-L samples were collected from each of the three sites in Wuyuanwan (inner bay, bay mouth, and outer bay) using a stainless-steel bucket, with replicates spaced approximately 10 m apart to ensure spatial independence.

2.2. Microplastic Extraction and Identification

2.2.1. Sediment Samples

From each replicate sediment sample collected from the field, three laboratory subsamples (10 g each) were weighed and processed for microplastic extraction. All extraction and identification procedures were performed for each subsample, and the results were averaged per field replicate. Microplastics were extracted using density flotation with saturated NaCl solution (density ≈ 1.2 g/cm^3). The supernatant was filtered through 0.45-μm glass fiber filters. The filters were examined under a stereomicroscope (Olympus SZX16) for particle counting and morphological classification. Polymer identification was performed using a micro-Fourier transform infrared (μ-FTIR) spectrometer (Thermo Scientific Nicolet iN10). All extraction and identification procedures were performed for each replicate, and the results were averaged. It should be noted that density flotation with saturated NaCl solution (density ≈ 1.2 g/cm^3) is effective for the recovery of low-density polymers such as PE (0.91 - 0.96 g/cm^3) and PS (1.04 - 1.05 g/cm^3), but may under-recover denser polymers such as PA (1.13 - 1.15 g/cm^3) and would not efficiently recover high-density polymers such as PET (≈1.38 g/cm^3) or PVC (≈1.4 g/cm^3). Therefore, the abundance data reported in this study should be interpreted as the fraction of microplastics recoverable at the NaCl density threshold, rather than the total microplastic burden in the sediments.

2.2.2. Water Samples

For each sampling site (inner bay, bay mouth, and outer bay), three replicate water samples (10 L each) were collected and filtered through 0.45-μm glass fiber filters.

The filters were examined under a stereomicroscope, and microplastics were counted and classified by color, morphology, and size. Particles were categorized into five morphological groups: fragments, films, fibers, foams, and pellets. Size fractions were classified as <200 μm, 200 - 500 μm, 500 - 1000 μm, and 1000 - 5000 μm. Color groups included white, black, red, yellow, blue, and green. All counting and classification procedures were performed for each replicate, and the results were averaged.

Polymer identification was performed by μ-FTIR (Thermo Scientific Nicolet iN10) in attenuated total reflectance (ATR) mode, with spectra recorded over the range of 4000 - 650 cm^{-1} at a resolution of 4 cm^{-1}. For each sampling site, all particles that were visually identified as suspected microplastics under the stereomicroscope (*i.e.*, particles with no obvious biological or mineralogical structure, uniform color, and synthetic appearance) were subjected to μ-FTIR analysis. The resulting spectra were compared against a commercial polymer spectral library (e.g., Thermo Scientific Polymers Library) and an in-house reference library. Only particles with a spectral match ≥ 70% were confirmed as synthetic polymers and included in the abundance data. Particles that did not meet this criterion, or that produced spectra of insufficient quality, were recorded as "unidentified" and excluded from all quantitative analyses. For each sampling site, the proportion of visually suspected particles that were confirmed as polymers by μ-FTIR exceeded 90%.

The confirmed polymer types included PE, PS, PP, and PA; fragments were the most frequently detected morphology. No particles of non-plastic origin (e.g., cellulose, chitin, or inorganic minerals) were included in the counts.

2.2.3. Quality Control

To prevent contamination, all glassware was rinsed with deionized water and filtered before use. Cotton lab coats and nitrile gloves were worn during all procedures. Procedural blanks were processed alongside samples, and no microplastics were detected in the blanks.

To avoid false positives due to contamination, all μ-FTIR measurements included background scans and blank filter controls. No polymer peaks were detected in procedural blanks.

2.3. Degradation Experiment in Mangrove Sediment Microcosms

2.3.1. Experimental Setup

Four types of microplastic particles were used: polyethylene (PE, yellow, 500 - 1000 μm), polystyrene (PS, white, 500 - 1000 μm), polyamide (PA/Nylon, blue, 500 - 1000 μm), and fishing net fragments (nylon-based, white). All microplastic materials were purchased from Shenzhen Chenmei Pigment Masterbatch Co., Ltd., China. Three replicate microcosms were established for each plastic type. Each microcosm consisted of a 30-L glass tank containing 10 L of artificial seawater (salinity 25‰) and 5 cm of mangrove sediment (collected from Xiatanwei) mixed with quartz sand (1:1 ratio). Known amounts of each plastic type were weighed (initial weights rec-

orded) and mixed into the sediment. The tanks were maintained under controlled conditions: temperature 25˚C, photoperiod 12-h light/12-h dark, and daily tidal simulation (12-h submerged/12-h exposed) for 6 months.

After 6 months, the microplastic particles were carefully recovered from the sediment by manual sorting under a stereomicroscope. The recovered particles were cleaned, dried, and identified following the same procedures described in Section 2.2.1. The number of recovered particles from each microcosm was counted, and the average weight per particle was calculated. The weight loss for each plastic type was then calculated based on the average weight before and after incubation, using the formula:

$$\text{Weight loss}(\%) = \frac{W_{\text{initial}} - W_{\text{recovered}}}{W_{\text{initial}}} \times 100\%$$

where W_{initial} is the average initial weight per particle and $W_{\text{recovered}}$ is the average weight per particle after 6 months of incubation.

To distinguish biologically mediated mass loss from procedural artifacts (e.g., particle loss during handling, cleaning, and weighing, as well as physical abrasion and leaching), an abiotic control was conducted in parallel with the sediment microcosms. For each polymer type, 200 particles were placed in sterile artificial seawater (salinity 25‰) in sealed glass containers without sediment and incubated under identical conditions (temperature 25˚C, 12-h light/12-h dark photoperiod) for the same 6-month duration. The control particles were recovered, cleaned, dried, and weighed following the exact same protocol as the treatment samples.

2.3.2. Statistical Analysis

All data were expressed as mean ± standard deviation (SD) from three replicates. One-way analysis of variance (ANOVA) followed by Tukey's post-hoc test was used to compare weight loss among different plastic types. A p-value < 0.05 was considered statistically significant. Statistical analyses were performed using GraphPad Prism 9.5.1.

3. Results

3.1. Microplastic Abundance in Sediment Samples

The total microplastic abundances in sediments from different tidal zones are presented in **Figure 1**. Low-tide mud exhibited the highest abundance (8.0 items/10 g), followed by high-tide mud (4.2 items/10 g), while mangrove sediments showed the lowest value (2.3 items/10 g). The size-fractionated data (**Figure 1**, inset) further revealed that particles < 200 μm constituted the dominant size fraction across all sediment types, with low-tide mud showing the highest count (4.3 items/10 g). In the Xiatanwei wetland, the NaCl-recoverable microplastic abundance (*i.e.*, particles with density ≤ ≈1.2 g/cm^3) was 483 items/kg, which is substantially lower than that reported for the Jiulong River estuary mangrove wetland (640 - 1140 items/kg, mean 935 items/kg[9]).

The sampling locations in Xiatanwei are shown in **Figure 2**.

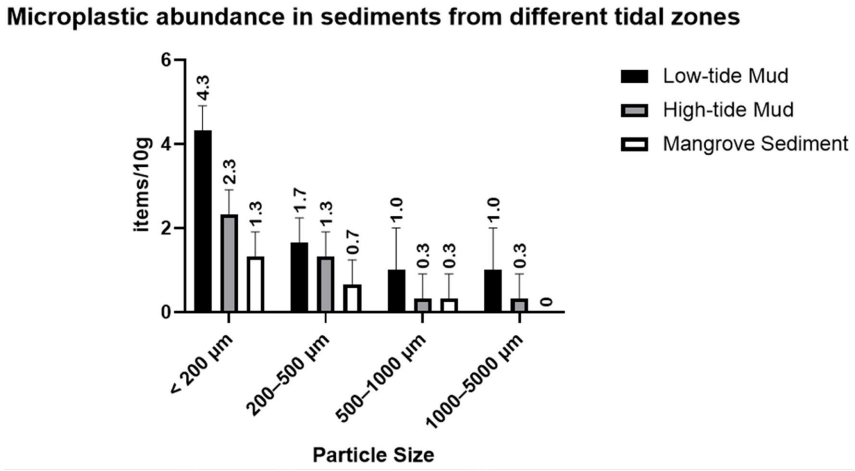

Figure 1. Microplastic abundance in sediments from different tidal zones. (A) Total abundance (items/10 g) in low-tide mud, high-tide mud, and mangrove sediments. (B) Size-fractionated abundance (<200 μm, 200 - 500 μm, 500 - 1000 μm, and 1000 - 5000 μm). Data are presented as mean ± SD $n = 3$.

Figure 2. Sampling locations in Xiatanwei Coastal Wetland Park, Xiamen, Fujian, China.

3.2. Microplastic Characteristics in Water Samples from Wuyuanwan

3.2.1. Color Composition

The color composition of microplastics in water samples from inner bay, bay mouth, and outer bay is shown in Figure 3. White microplastics were most abundant in the inner bay (504 items/m^3) and bay mouth (501 items/m^3), while black particles showed the highest abundance at the bay mouth (960 items/m^3). Red particles were present in the bay mouth at a relatively low concentration (64 items/m^3). This distribution pattern suggests that the color composition of micro-

plastic pollutants lacks a distinct environmental or hydrodynamic sorting pattern, and is largely dictated by local anthropogenic activities (e.g., discharge sources, land-based inputs, and human use patterns).

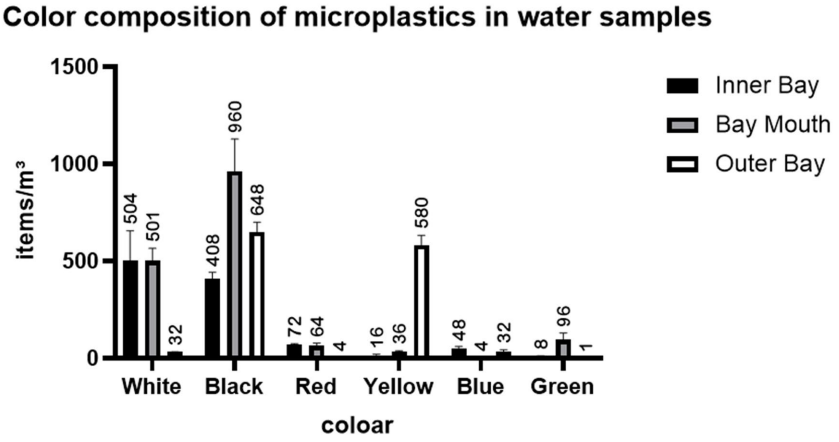

Figure 3. Color composition of microplastics in water samples from inner bay, bay mouth, and outer bay (items/m³).

3.2.2. Morphological Composition

The morphological composition of microplastics is presented in Figure 4. Fragments were the dominant morphology at all three sites, with the highest abundance in the bay mouth (1234 items/m³), followed by the outer bay (634 items/m³) and inner bay (613 items/m³). Films were detected in the inner bay (388 items/m³), outer bay (615 items/m³) and bay mouth (289 items/m³), while fibers were most observed in the bay mouth. Pellets and foams were almost not detected at any site.

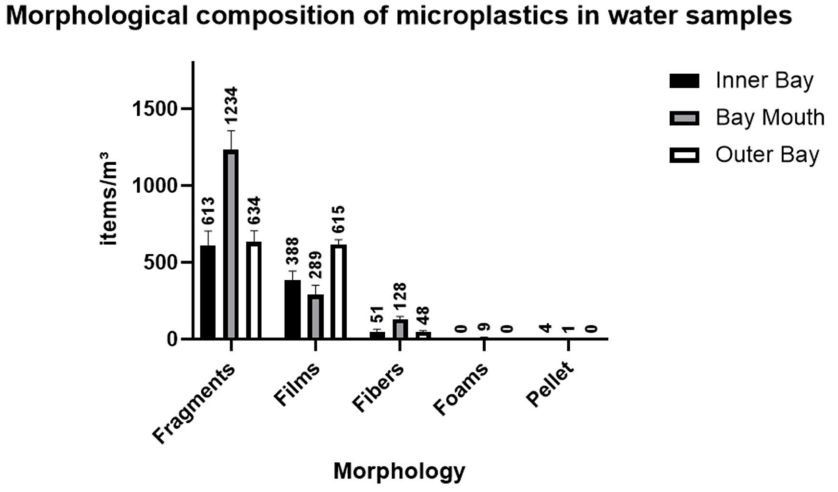

Figure 4. Morphological composition of microplastics in water samples from inner bay, bay mouth, and outer bay (items/m³). Fragments were the dominant type at all sampling sites.

3.2.3. Size Distribution

The size distribution of microplastics is shown in Figure 5. The <200 μm fraction

was the most abundant across all sites, with the bay mouth showing the highest value (1164 items/m^3), followed by the outer bay (1064 items/m^3) and inner bay (812 items/m^3). The 200 - 500 μm fraction showed a similar pattern, with the bay mouth (416 items/m^3) exceeding the inner bay (202 items/m^3) and outer bay (209 items/m^3). Larger particles (500 - 1000 μm and 1000 - 5000 μm) were only detected in small numbers, with a decreasing trend from bay mouth to outer bay.

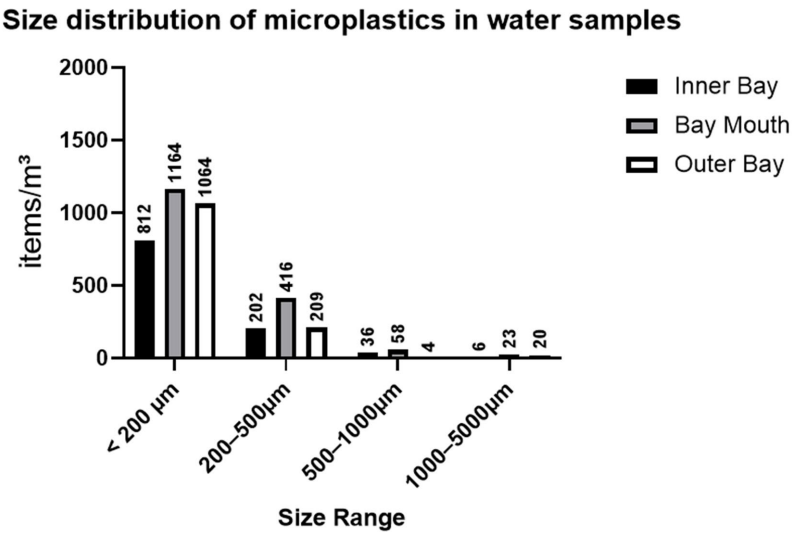

Figure 5. Size distribution of microplastics in water samples from inner bay, bay mouth, and outer bay (items/m^3). The <200 μm fraction was the most abundant across all sites.

3.2.4. Total Microplastic Abundance

The total microplastic abundances are summarized in Figure 6. The bay mouth exhibited the highest abundance (1661 items/m^3), followed by the outer bay (1297 items/m^3), while the inner bay showed the lowest abundance among the three sites (1056 items/m^3).

The sampling stations in Wuyuan Bay are shown in Figure 7.

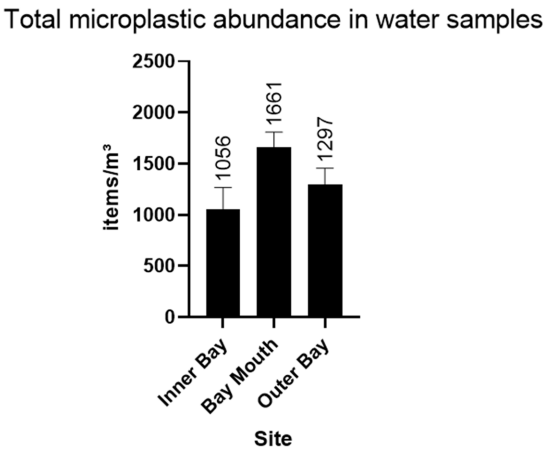

Figure 6. Total microplastic abundance in water samples from inner bay, bay mouth, and outer bay (items/m^3).

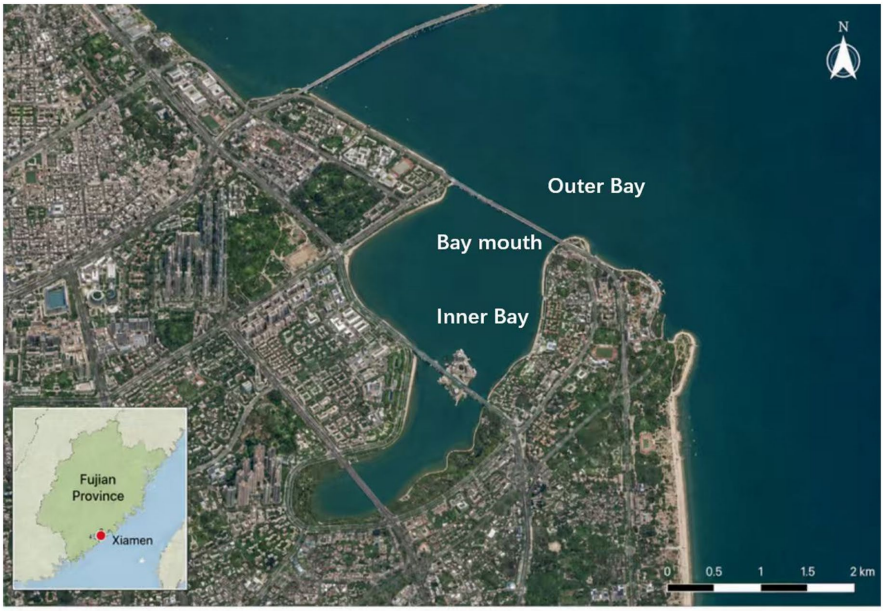

Figure 7. Sampling stations in Wuyuanwan.

3.3. Degradation of Microplastics in Mangrove Sediment Microcosms

The weight loss of PE, PS, PA, and fishing net fragments after 6 months of incubation in mangrove sediments is presented in Figure 8. Among the four materials, PS showed the highest weight loss (6.02% ± 1.66%), followed by PE (3.07% ± 0.86%). PA exhibited only 0.56% ± 0.18% weight loss, while fishing net fragments showed 0.52% ± 0.05% weight loss. ANOVA revealed significant differences among groups $F(3,8)=18.54$, $p < 0.001$. Post-hoc tests indicated that PS was significantly higher than PA and fishing net ($p < 0.01$), while PE was also significantly higher than PA and fishing net ($p < 0.05$). There was no significant difference between PA and fishing net ($p > 0.05$). The average mass loss in the abiotic controls was less than 0.05%, confirming that the weight losses observed in the sediment treatments (2% - 6%) were primarily attributable to sediment-associated biological processes rather than non-biological handling or physical losses.

Table 1 summarizes the initial and recovered particle counts, initial and recovered dry mass, and calculated mass loss for each of the three replicate microcosms of polyethylene (PE), polystyrene (PS), polyamide (PA), and fishing net fragments. For all polymer types except fishing net, each microcosm started with 200 particles. The recovery rates exceeded 96% in all cases, confirming that the observed mass losses were not due to particle loss during recovery and handling. PS exhibited the highest mass loss (6.02% ± 1.66%, mean ± SD), followed by PE (3.07% ± 0.86%), while PA (0.56% ± 0.18%) and fishing net (0.52% ± 0.05%) showed minimal degradation.

Table 1. Particle recovery and mass loss data for each microcosm after 6 months of incubation in mangrove sediments.

Polymer type	Replicate	Initial particle count	Recovered particle count	Initial dry mass (g)	Recovered dry mass (g)	Mass loss (%)
PE	1	200	200	1.6989	1.6423	3.33%
PE	2	200	200	1.6638	1.6284	2.13%
PE	3	200	200	1.6847	1.6213	3.76%
PS	1	200	200	2.0447	1.9044	6.86%
PS	2	200	200	2.1536	2.0011	7.08%
PS	3	200	200	2.0548	1.9704	4.11%
PA	1	200	200	1.1599	1.1527	0.62%
PA	2	200	200	1.1243	1.1202	0.36%
PA	3	200	200	1.1512	1.1430	0.71%
Fishing net	1	—	—	0.1466	0.1458	0.55%
Fishing net	2	—	—	0.2157	0.2147	0.46%
Fishing net	3	—	—	0.1652	0.1643	0.54%

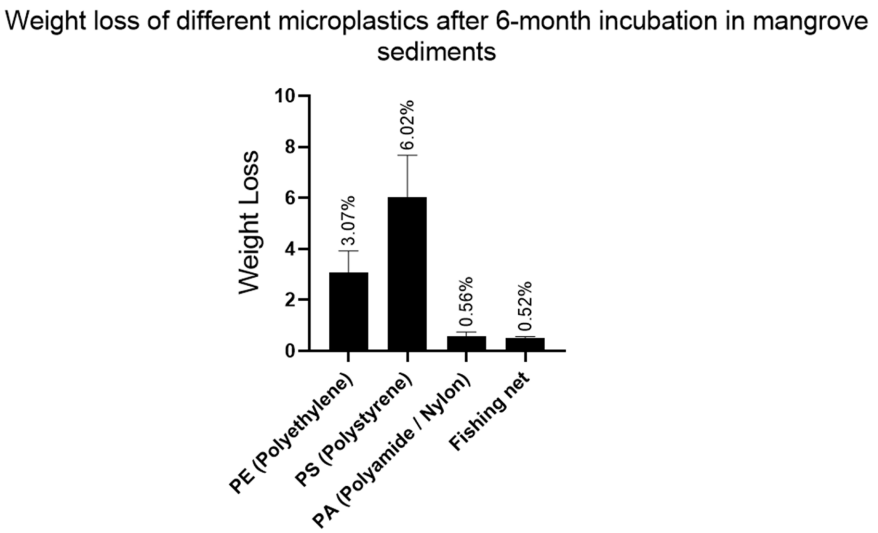

Figure 8. Weight loss of polyethylene (PE), polystyrene (PS), polyamide (PA), and fishing net fragments after 6 months of incubation in mangrove sediments. Data are presented as mean ± SD $n = 3$. The highest weight loss was observed in PS (6.02% ± 1.66%), followed by PE (3.07% ± 0.86%), while PA (0.56% ± 0.18%) and fishing net (0.52% ± 0.05%) showed minimal degradation, $p < 0.05$.

4. Discussion

4.1. Microplastic Distribution in Mangrove Sediments and Water

The field data from Xiatanwei and Wuyuanwan provide valuable insights into microplastic contamination in mangrove-adjacent coastal environments. The higher microplastic abundance in low-tide mud (8.0 items/10 g) compared to mangrove sediments (2.3 items/10 g) is consistent with the hypothesis that mangroves may

act as physical barriers, potentially trapping microplastics in their root systems. However, as the sampling design was cross-sectional, this spatial pattern cannot unequivocally confirm a trapping mechanism; alternative explanations—such as site-specific differences in hydrodynamic conditions, sediment deposition rates, or proximity to pollution sources—may also contribute to the observed gradient [7]. This is consistent with the observation that mangrove wetlands are effective sinks for microplastics [11].

However, the abundance in Xiatanwei (483 items/kg) was considerably lower than that in the Jiulong River estuary (640 - 1140 items/kg[9]). This difference may reflect variations in surrounding land use, hydrological conditions, and the extent of anthropogenic activities. Xiatanwei is likely less impacted by industrial and urban effluents compared to the Jiulong River estuary, which receives inputs from a densely populated watershed.

In Wuyuanwan, the bay mouth exhibited the highest abundance (1661 items/m^3), followed by the outer bay (1297 items/m^3), while the inner bay showed the lowest abundance among the three sites (1056 items/m^3). The relatively lower abundance in the inner bay compared to the bay mouth may be attributed to local hydrodynamic conditions (e.g., tidal flushing that dilutes or transports particles out of the inner bay), sampling location differences, or the possibility that the inner bay is not the primary source area in this system. The bay mouth may serve as a convergence zone where microplastics from both inner bay and outer bay sources accumulate [12].

The morphological composition of microplastics is presented in **Figure 4**. Fragments were the dominant morphology at all three sites, with the highest abundance at the bay mouth (1234 items/m^3), followed by the outer bay (634 items/m^3) and inner bay (613 items/m^3). The dominance of fragments across all water samples suggests that secondary microplastics derived from the fragmentation of larger plastic debris are the main contributors to pollution in this area [2]. Films were detected in the inner bay (388 items/m^3), outer bay (615 items/m^3) and bay mouth (289 items/m^3). Fibers were predominantly observed at the bay mouth. Pellets and foams were almost not detected at any site. This morphological distribution indicates that fragment-type microplastics are the most widespread form in Wuyuanwan, while fibrous and film-type particles show more localized occurrence patterns [13].

4.2. Degradation of Different Microplastics in Mangrove Sediments

The 6-month incubation experiment revealed distinct degradation behaviors among the four tested materials, which can be explained by differences in their chemical structures and susceptibility to microbial attack.

Polystyrene (PS) exhibited the highest weight loss (6.02%), consistent with its relatively low chemical stability and susceptibility to photo-oxidation and microbial degradation [8]. PS contains a phenyl group that is vulnerable to attack by

reactive oxygen species, and its degradation has been shown to involve organisms such as *Sphingomonadaceae* [10]. The significant weight loss observed in this study confirms that mangrove sediments harbor microbial communities capable of PS degradation.

Polyethylene (PE) showed moderate weight loss (3.07%), which is within the range expected for this recalcitrant polymer [9]. PE is composed of a simple linear hydrocarbon chain with no easily breakable functional groups, making it resistant to microbial attack. However, certain bacteria isolated from mangrove environments, such as *Bacillus* and *Lysinibacillus*, have been shown to degrade PE by producing extracellular enzymes that oxidize the polymer chain [9]. The moderate degradation observed in this study suggests that similar mechanisms are active in our mangrove sediment microcosms.

Polyamide (PA) and fishing net fragments showed minimal weight loss (<1%), confirming that nylon-based polymers are highly resistant to biodegradation in sedimentary environments [14]. PA is characterized by amide bonds that are relatively stable under environmental conditions, and its degradation requires specialized enzymes that are not commonly present in natural microbial communities [11]. The slight weight loss observed (<0.6%) may be due to physical fragmentation and surface erosion rather than true biodegradation.

The similar degradation rates observed for PA and fishing net fragments (0.56% vs. 0.52%) suggest that both materials are essentially recalcitrant. This is not surprising given that fishing nets are typically made of nylon (PA) or other synthetic polymers. The lack of significant degradation highlights the persistent nature of fishing net debris in the marine environment, emphasizing the urgent need for better waste management practices.

4.3. Environmental Implications and Bioremediation Potential

The findings of this study have several important environmental implications. First, the field data confirm that mangrove wetlands are important sinks for microplastics. The substantial accumulation of microplastics in mangrove sediments indicates that these ecosystems play a critical role in intercepting land-based pollutants before they reach the open ocean. This reinforces the conservation value of mangroves beyond their well-known roles in shoreline protection, carbon sequestration, and biodiversity support.

Second, the degradation experiment provides experimental evidence that mangrove sediments possess intrinsic microplastic-degrading capacity. Although the weight loss over 6 months was modest (3% - 6% for PS and PE), the fact that degradation occurred at all in such a short period is encouraging. The degradation rates may be enhanced by optimizing environmental conditions (e.g., nutrient availability, oxygen levels) or by introducing specific microbial consortia [8] [10].

Third, the wide variation in degradation rates among polymer types underscores the importance of considering plastic composition when assessing environmental risks. PS and PE, which are widely used in packaging and consumer prod-

ucts, are more amenable to degradation than PA, which is used in textiles and fishing gear. This suggests that efforts to reduce microplastic pollution should prioritize the development of more degradable alternatives for high-risk applications.

Finally, the minimal degradation of fishing net fragments in this study emphasizes the long-term persistence of ghost fishing gear in the marine environment. Given that fishing nets constitute a significant proportion of marine plastic litter, strategies such as net recycling programs, use of biodegradable net materials (e.g., PBS-based nets), and retrieval of lost gear should be promoted to mitigate their environmental impacts [11].

4.4. Limitations and Future Research

This study has several limitations. First, the degradation experiment was conducted under controlled laboratory conditions, which may not fully represent the complexity of natural mangrove ecosystems. Future studies should consider in situ incubation experiments to validate the observed degradation rates. Second, the experiment lasted only 6 months; longer-term studies (e.g., 1 - 2 years) would provide a more complete picture of degradation dynamics. Third, field sampling was subject to natural and anthropogenic constraints, including weather conditions, tidal fluctuations, and human activities in the sampling areas, which may have introduced variability in the collected samples and limited their representativeness. Consequently, the observed microplastic abundances should be interpreted as preliminary baselines rather than definitive assessments of the study sites. Future surveys with multiple seasonal campaigns and standardized sampling protocols are needed to better constrain the spatial and temporal variability of microplastic pollution in these coastal ecosystems. Fourth, the use of saturated NaCl solution for density flotation selectively recovers polymers with densities below approximately 1.2 g/cm^3. While this is a widely adopted method in microplastic surveys, it may underestimate the abundance of denser polymers such as PET and PVC. Consequently, the abundance values reported here represent the NaCl-recoverable fraction and should not be interpreted as absolute total microplastic concentrations. Future studies could employ sequential flotation with higher-density solutions, such as $ZnCl_2$ (density ≈ 1.5 - 1.7 g/cm^3) or NaI (density ≈ 1.6 - 1.8 g/cm^3), to achieve a more comprehensive recovery of polymer types. In addition, future work should explore the role of specific microbial taxa in the degradation process. Metagenomic analysis of the sediment microbiome before and after incubation could identify key players involved in plastic degradation, facilitating the development of microbial-based bioremediation strategies [12]. Finally, the field sampling was cross-sectional and therefore cannot establish causal relationships between mangrove presence and microplastic abundance patterns. While the observed spatial distribution is consistent with a trapping effect, alternative explanations—such as differences in sediment deposition rates, hydrodynamic conditions, or proximity to sources—cannot be ruled out. Future studies

using time-series monitoring or sediment core analysis would help clarify the mechanisms underlying microplastic accumulation in mangrove sediments.

5. Conclusions

This study investigated microplastic contamination in mangrove-adjacent coastal environments and evaluated the degradation of four common microplastic types in mangrove sediment microcosms. The key findings are summarized as follows:

1) Microplastic abundance in mangrove sediments varies by tidal zone and location. In Xiatanwei, the total microplastic abundance was 483 items/kg, with low-tide mud (8.0 items/10 g) showing significantly higher concentrations than mangrove sediments (2.3 items/10 g), suggesting that mangrove root systems may act as physical barriers that trap microplastics. However, the cross-sectional nature of the field sampling does not allow us to definitively establish the trapping mechanism, as sediment deposition history and local hydrodynamics could also influence the observed spatial patterns. This abundance was substantially lower than that reported for the Jiulong River estuary (640 - 1140 items/kg), highlighting the influence of local anthropogenic activities and hydrological conditions on microplastic accumulation.

2) Spatial distribution in Wuyuanwan reveals strong land-based inputs. The bay mouth exhibited the highest total abundance (1661 items/m^3), followed by the outer bay (1297 items/m^3) and the inner bay (1056 items/m^3). Fragments were the dominant morphology across all sites, with the highest abundance at the bay mouth (1234 items/m^3), and the <200 μm size fraction was the most abundant, indicating that secondary microplastics from fragmentation of larger debris are the primary contributors.

3) Degradation efficiency is highly polymer-dependent. In the 6-month mangrove sediment incubation experiment, polystyrene (PS) showed the highest weight loss (6.02% ± 1.66%), followed by polyethylene (PE) (3.07% ± 0.86%). In contrast, polyamide (PA) (0.56% ± 0.18%) and fishing net fragments (0.52% ± 0.05%) exhibited minimal degradation, confirming that nylon-based materials are highly recalcitrant in sedimentary environments. This polymer-dependent pattern is consistent with literature data and reflects differences in chemical structure and susceptibility to microbial attack.

4) Mangrove sediments possess intrinsic but selective microplastic-degrading capacity. The observed degradation, even at modest levels, provides experimental evidence that mangrove sediments harbor microbial communities capable of attacking certain polymer types. However, the efficiency varies significantly, with PS and PE being more amenable to degradation than PA and fishing nets.

Collectively, these findings contribute to the growing body of knowledge on microplastic fate in coastal ecosystems and provide empirical support for the role of mangrove wetlands in microplastic interception and degradation. The persistence of fishing net fragments underscores the urgent need for improved waste management strategies, including fishing gear recycling programs, the develop-

ment of biodegradable net materials (e.g., PBS-based nets), and the retrieval of lost gear. Future research should employ molecular-level analyses (e.g., SEM, FTIR, GC-MS) and metagenomic approaches to elucidate the degradation mechanisms and identify key microbial taxa involved in plastic breakdown, which would facilitate the development of microbial-based bioremediation strategies for microplastic-contaminated coastal sediments.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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