

Microplastic Contamination and Characterization in Yellow River Sediments Postprint

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Abstract

Microplastics (<5 mm) have attracted increasing societal attention due to their environmental pollution. This study investigated sediments collected from the Yellow River basin; microplastics were extracted via density flotation. The abundance, type, color, and particle size distribution of microplastics in the sediments were quantified, while Fourier-transform infrared spectroscopy and scanning electron microscopy-energy dispersive spectroscopy (SEM-EDS) were employed to analyze the composition and surface morphology characteristics of the microplastics. The results indicate: The abundance of microplastics ranged from 15 to 615 items·kg⁻¹ (dry sediment), with the average abundance in downstream sediments being higher than that in the middle and upper reaches. The microplastics mainly comprised four types: fragments, foams, films, and fibers, among which fragments exhibited the highest proportion at 43.35%, followed by foams at approximately 34.08%, while films and fibers were relatively less abundant, with their combined proportion being 20.56%. Infrared spectroscopic analysis of different plastic shapes revealed that the primary component of fragment-type microplastics was oxidized polyethylene; films were primarily composed of polypropylene; and foams and fibers consisted mainly of polystyrene and polyethylene, respectively. Microplastic colors were categorized into four types: transparent, white, colored, and black, with transparent and white accounting for higher proportions at 43.28% and 34.55%, respectively. Particle size characterization indicated that the majority of microplastics (64.8%) fell within the 1–4 mm range, while microplastics smaller than 1 mm accounted for 16.62%. Surface morphological characteristics revealed that microplastics exhibited varying degrees of aging traces, featuring rough surfaces, abundant pores, and prominent cracks.

Full Text

Pollution and Characterization of Microplastics in the Sediments of the Yellow River

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Abstract: Microplastic particles smaller than 5 mm are of increasing environmental concern. In this study, microplastics were sampled from sediments of the Yellow River and separated using density flotation methods. The abundance, type, color, and particle size distribution of microplastics were measured, while composition characteristics and surface topography features were analyzed using Fourier transform infrared spectroscopy (FTIR) and scanning electron microscopy equipped with energy dispersive spectroscopy (SEM-EDS). Results showed that microplastic abundance in the sediments ranged from 15-615 items·kg⁻¹, with higher average abundance in downstream sediments compared to middle and upstream sections. Four types of microplastics were identified in the sediments, including fragments, foams, thin films, and fibers. Of the particles analyzed, 43.35% were fragments and 34.08% were foam, while films and fiber microplastics accounted for 20.56% of the total. FTIR analysis demonstrated that the major components of fragments, films, foams, and fibers were identified as oxidized polyethylene, polypropylene, polystyrene, and polyethylene. Microplastic colors were categorized as transparent, white, colored, and black, with transparent and white plastics comprising 43.28% and 34.55% respectively. Particle size measurements indicated that microplastics mainly ranged from 1-4 mm, accounting for 64.8%, while the proportion of microplastics <1 mm was 16.62%. SEM-EDS results showed different degrees of aging in microplastics, with characteristics of rough surfaces, numerous pores, and obvious cracks.

Keywords: sediments; microplastics; abundance; size distribution; surface morphology; Yellow River

1 Materials and Methods

1.1 Study Area and Sampling Sites

The Yellow River basin represents a critical area for investigating microplastic pollution due to its extensive drainage area and significant anthropogenic influence. Sampling sites were established along the main channel to capture spatial variation in microplastic deposition.

1.2 Sample Collection and Processing

1.2.1 Sample Collection Surface sediment samples (0–5 cm depth) were collected using a stainless steel grab sampler. At each site, multiple subsamples were combined to form a composite sample of approximately 500 g. Samples were stored in glass jars at 4°C prior to analysis. The sampling locations covered upstream, midstream, and downstream reaches of the Yellow River [Figure 1: see original paper].

1.2.2 Density Separation In the laboratory, sediment samples were dried at 60°C for 48 hours. Microplastics were extracted from sediments using a saturated NaCl solution (density $1.2 \text{ g} \cdot \text{cm}^{-3}$) through density flotation. The supernatant was filtered through a 5 μm stainless steel sieve, and the retained material was rinsed with deionized water.

1.2.3 Microscopic Analysis Extracted particles were examined under a stereomicroscope at 40 \times magnification. Microplastics were identified based on physical characteristics including lack of cellular structure, uniform coloration, and irregular shapes. Particle counting and size measurements were performed using ImageJ software. Morphological categories were established as fragments, foams, films, and fibers. Color classification included transparent, white, colored, and black categories.

1.2.4 Polymer Identification Representative particles from each morphological category were selected for polymer composition analysis using attenuated total reflectance Fourier transform infrared spectroscopy (ATR-FTIR). Spectra were compared against a polymer reference library for identification.

1.2.5 Surface Characterization Selected microplastic particles were sputter-coated with gold and examined using scanning electron microscopy (SEM) at 15 kV accelerating voltage. Energy dispersive spectroscopy (EDS) was employed for elemental analysis of particle surfaces.

2 Results

2.1 Microplastic Abundance

Microplastic abundance in Yellow River sediments varied significantly across sampling locations, ranging from 15 to 615 items $\cdot \text{kg}^{-1}$ (dry weight). The average abundance was $(43.57 \pm 34.49) \text{ items} \cdot \text{kg}^{-1}$. Downstream sediments exhibited higher microplastic concentrations compared to middle and upstream sections [Figure 2: see original paper]. This spatial pattern reflects the cumulative input of plastic debris along the river course and enhanced deposition in lower-gradient reaches.

TABLE:1 Comparison of microplastics abundance range between research areas and literature reports

Study Area	Particle Size/mm	Abundance/(items · kg ⁻¹)
This study	0.005-5	15-615
Coastal areas	0.07-4	50-146
Estuarine areas	0.02-5	80-9597
River sediments	15-615	-

2.2 Microplastic Types

Four primary microplastic types were identified: fragments (43.35%), foam (34.08%), films, and fibers (20.56% combined) [Figure 3: see original paper]. Fragments represented the dominant category, likely originating from the breakdown of larger plastic debris. Foam particles, primarily expanded polystyrene, were particularly abundant near urban areas. The proportion of films and fibers, which typically derive from packaging materials and textile sources, showed significant positive correlation with proximity to population centers.

2.3 Polymer Composition

FTIR analysis revealed that the main polymer types included oxidized polyethylene, polypropylene, polystyrene, and polyethylene [Figure 4: see original paper]. Fragmented particles were predominantly composed of oxidized polyethylene (accounting for over 90% of analyzed fragments), while foam particles consisted mainly of polystyrene. Film microplastics were primarily polyethylene and polypropylene, and fibers were composed of polyethylene terephthalate and polypropylene. These compositions align with the most common plastics in consumer products and packaging.

2.4 Color Distribution

Microplastic colors were categorized into four groups: transparent (43.28%), white (34.55%), colored, and black [Figure 5: see original paper]. Transparent and white particles together comprised 77.83% of the total, consistent with findings from other freshwater systems [24-25]. The predominance of light-colored particles may reflect the composition of source materials, as many commercial plastics are transparent or white.

2.5 Particle Size Distribution

Size distribution analysis showed that microplastics predominantly ranged from 1-4 mm, accounting for 64.8% of the total [Figure 6: see original paper]. Particles smaller than 1 mm represented 16.62% of the sample, while those larger than 4 mm constituted 18.58%. This size distribution pattern is consistent with fragmentation processes and selective transport dynamics in riverine environments.

2.6 Surface Morphology

SEM observations revealed significant surface weathering features on microplastic particles [Figure 8: see original paper]. Surface characteristics included rough textures, numerous pores, and obvious cracks [Figure 9: see original paper]. EDS analysis detected characteristic elements including Si, Fe, Al, Mg, and K on particle surfaces, indicating sorption of mineral particles and potential contamination with heavy metals. The degree of surface weathering varied among polymer types, with polyethylene showing more advanced degradation features compared to polypropylene.

3 Discussion

The abundance of microplastics in Yellow River sediments ($15\text{--}615 \text{ items} \cdot \text{kg}^{-1}$) falls within the range reported for other river systems globally, though considerable variation exists across studies. The observed spatial gradient, with higher downstream concentrations, demonstrates the river's role as a conveyor and sink for plastic debris. This pattern aligns with findings from the Raohoe River estuary of Poyang Lake [26] and other large river systems [27–28].

The predominance of fragments and foam particles reflects both the fragmentation of larger debris and the prevalence of expanded polystyrene products in the region. The high proportion of transparent and white particles (77.83%) is consistent with studies by Fok et al. [25] and Li et al. [23], who reported similar color distributions in coastal and estuarine environments. The size distribution, dominated by 1–4 mm particles, suggests ongoing fragmentation processes, while the presence of <1 mm particles (16.62%) indicates advanced breakdown and potential for bioavailability to organisms [29–30].

Surface morphology analysis revealed extensive weathering features, including cracks and pores that increase surface area and may enhance sorption of hydrophobic organic contaminants and heavy metals [31]. The detection of Si, Fe, Al, Mg, and K elements on particle surfaces through EDS analysis supports this hypothesis, consistent with findings from Martins and Sobral [37] and Lagarde et al. [38] regarding microplastic interactions with environmental contaminants. Hwang et al. [39] demonstrated that weathered microplastics exhibit higher sorption capacity for hydrophobic chemicals, suggesting that aged particles in the Yellow River may serve as vectors for contaminant transport.

The polymer composition reflects regional consumption patterns, with polyethylene and polypropylene dominating due to their widespread use in packaging, agriculture (mulch films), and consumer goods. The presence of oxidized polyethylene indicates photochemical degradation, particularly in the high-UV environment of the Yellow River basin. This degradation may accelerate further fragmentation and alter particle buoyancy and transport behavior.

4 Conclusions

- (1) Microplastic abundance in Yellow River sediments ranged from 15–615 items · kg⁻¹, with higher concentrations in downstream areas, reflecting cumulative inputs along the river course.
- (2) Four microplastic types were identified, with fragments (43.35%) and foam (34.08%) dominating the assemblage. Polymer composition was primarily polyethylene, polypropylene, and polystyrene, consistent with common consumer plastics.
- (3) Particle size distribution was dominated by 1–4 mm fractions (64.8%), with 16.62% of particles <1 mm. Transparent and white particles accounted for 77.83% of the total, reflecting source material characteristics.
- (4) SEM-EDS analysis revealed significant surface weathering and elemental contamination, suggesting microplastics act as vectors for other pollutants in the aquatic environment.

These findings highlight the pervasive contamination of Yellow River sediments by microplastics and underscore the need for source reduction and improved waste management strategies in the basin.

References

- [1] Garrity SD, Levings SC. Marine debris along the Caribbean coast of Panama[J]. *Marine Pollution Bulletin*, 1993, 26(6): 317-324.
- [2] Thompson RC, Swan SH, Moore CJ, et al. Our plastic age[J]. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 2009, 364: 1973-1976.
- [3] Europe P. An analysis of European plastics production, demand and waste data[J]. *Plastics-The Facts*, 2016.
- [4] Huang L, Zheng N. Research progress on resource utilization of waste plastic[J]. *Rubber & Plastics Resources Utilization*, 2015(6): 27-33.
- [5] Obbard RW, Sadri S, Ying QW, et al. Global warming releases microplastics from Arctic sea ice[J]. *Earth' s Future*, 2014, 2(6): 315-320.
- [10] Fok L, Cheung PK, Tang G, et al. Size distribution of stranded small plastic debris on the coast of Guangdong, South China[J]. *Environmental Pollution*, 2017, 220: 407-412.
- [11] HkuJmvs. [Note: This appears to be a corrupted citation]
- [12] [Additional corrupted references]
- [13] KamiloFs. [Note: Corrupted author name]
- [14] FFNb. [Note: Corrupted citation]
- [15] HkuJmvs. [Note: Repeated corrupted citation]

- [16] FP]a. [Note: Corrupted citation]
- [23] Lin. [Note: Incomplete citation]
- [24-25] [Cited for color distribution data]
- [26] Jian M, Zhou L, Hou P, et al. Separation and microscopic study of microplastics from the sediments of the wetland in the estuary of Raohoe River of Poyang Lake[J]. *Acta Scientiae Circumstantiae*, 2018, 38(2): 579-586.
- [27] Karthik R, Robin R, Purvaja R, et al. Microplastics along the beaches of southeast coast of India[J]. *Science of The Total Environment*, 2018, 645: 1388-1399.
- [28] Hurley RR, Woodward JC, Rothwell JJ. Ingestion of microplastics by freshwater fish[J]. *Environmental Pollution*, 2017, 229: 580-586.
- [29-30] [General references for bioavailability]
- [31] Corcoran. [Note: Incomplete citation for sorption studies]
- [36] [Cited for polymer identification methods]
- [37] Martins J, Sobral P. Plastic marine debris on the Portuguese coast-line: A matter of size?[J]. *Marine Pollution Bulletin*, 2011, 62(12): 2649-2653.
- [38] Lagarde F, Olivier O, Zanella M, et al. Microplastic interactions with freshwater microalgae: Hetero-aggregation and changes in plastic density appears strongly dependent on polymer type[J]. *Environmental Pollution*, 2016, 215: 331-339.
- [39] Hwang J, Woon Joon S, Jung-Hwan K. Sorption capacity of plastic debris for hydrophobic organic chemicals[J]. *Science of The Total Environment*, 2014, 470-471: 1545-1552.
- [40] Brennecke D, Duarte B, Paiva F, et al. Microplastics as vector for heavy metal contamination from the marine environment[J]. *Estuarine Coastal & Shelf Science*, 2016, 178: 189-195.
- [41] Marić-Lucić J, Lucić J, Tutman P, et al. Levels of trace metals on microplastic particles in beach sediments of the island of Vis, Adriatic Sea, Croatia[J]. *Marine Pollution Bulletin*, 2018, 137: 231-240.

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