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# Unmasking Microplastic Pollution: A Study on the Distribution and Impact of Microplastics in Yuehai Lake, China

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ABSTRACT

The increasing use of plastics has led to a significant environmental challenge: microplastic (MP) pollution, which poses threats to aquatic ecosystems and human well-being. Freshwater habitats, including lakes, are particularly vulnerable to such contamination. This study investigates the characteristics and distribution of microplastics (MPs) in Yuehai Lake, China. Water samples were collected from five locations and analyzed using laser direct infrared (LDIR) spectroscopy to assess MP presence and concentration. MPs were detected at all sampling sites. The highest concentration, exceeding 1400 particles/L, was recorded at S5 (Lijing Street), while S1 (Yuehai Fishing Base), a site primarily used for fishing activities, recorded a concentration of 1100 particles/L. MP fragments were the predominant form (63.36%), followed by fibers (33.22%) and films (3.42%). Seventeen polymer types were identified, with fluororubber (FKM) being the most common (22.80%), followed by fluorosilicone rubber (FVMQ, 16.90%), chlorinated polyethylene (CPE, 13.58%), and polyvinyl chloride (PVC, 10.10%). The composition and morphology of MPs suggest automobile tire contamination as a primary source. Over 90% of the MPs detected were small-sized particles (20–100 μm). The Pollution Load Index (PLI) confirmed MP contamination at all sites. These findings provide essential insights to support governmental initiatives in environmental protection, policy development, and public awareness, contributing to improved ecological health and sustainability.

## INTRODUCTION

MP, referring to plastic particles smaller than 5 mm, have attracted widespread attention due to their environmental persistence. The invention of plastic materials in the middle of the 19th century, coupled

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with the development of numerous low-cost manufacturing techniques, allowed for the mass production of numerous lightweight, strong, inert, and corrosion-resistant plastic products (Plastics Europe Market Research Group, 2018). Since 1950, global plastic production has increased exponentially. The extensive use of plastic products and disposal methods, mainly in discarding, has incredibly pressured the ecological environment. Currently, the global consumption of plastic is in excess of 300 million tonnes. It is an emerging environmental pollutant which disperses in soil, water, and air. The physical characteristics of MP are considered to be dynamic. They are constantly decomposed over time to produce smaller MP, eventually forming less than 1 μm. Current estimates indicate that up to 40 megatons of MPs are released into the environment annually, and this number could double by 2040 without significant changes in plastic production and waste management (Harrison, 2024). Scherer et al. (2020) reported 5.57 MP items per cubic meter in Czech Elbe River water. In comparison, Lake Petit in Switzerland recorded 0.033 items/m³ (Sighicelli et al., 2018), Lake Winnipeg in Canada had 0.19 items/m³ (Anderson et al., 2017), and Lake Huron showed a much higher concentration of 3209 items/m³ (Zbyszewski et al., 2011). Concerns over the ecological risks and environmental harm from MP pollution have drawn global attention, with the 2016 United Nations Environment Conference identifying plastic pollution as the second most critical issue in environmental and ecological sciences.

MP pollution in freshwater habitats represents a significant environmental concern. A bibliometric analysis of 885 research articles published between 2013 and 2023 reveals a substantial yearly increase in research output, with an average growth rate of 73.13% (Yıldırım et al., 2024). Asia, particularly developing countries with less stringent waste management policies, is identified as having the highest levels of MP contamination (Chen et al., 2020). The Yangtze River has been recognized as one of the most significant sources of marine MP pollution globally, with surface water in the Yangtze River estuary containing up to 6500 items/m³ of MP, predominantly in the form of polyethylene (PE) fibers (Zhang et al., 2020). Comparatively, the MP concentration in the Hanjiang River, a tributary of the Yangtze, is lower, at around 2500-3000 items/m³ (Wang et al., 2018). In southeastern China, the Pearl River Estuary and Guangzhou City sections exhibit MP abundances of 8902 and 19860 items/m³, respectively, with polyamide and cellophane as the dominant MP components (Peng et al., 2017). The Beijiang River in South China, however, demonstrated lower levels of MP pollution (Luo et al., 2024).

While over 96% of MP research focuses on marine ecosystems (Browne et al., 2011; Xu et al., 2020), it is estimated that around 80% of marine MP originates from inland freshwater environments (Xu et al., 2020). As the world's largest producer and consumer of plastic, China faces a high risk of MP contamination (Zhang & Cheng, 2017), with substantial quantities of discarded plastics breaking down into MPs (Ma et al., 2023). Lakes, as significant bodies of inland freshwater, experience slower water exchange and renewal cycles compared to rivers and seas, making them more susceptible to MP accumulation (Dusaucy et al., 2021). MP pollution in lakes is becoming increasingly recognized as a serious issue, with studies indicating that it may be as problematic, if not more so, than in marine environments (Ding et al., 2019). Two of China's most developed regions, Taihu Lake and Poyang Lake, exhibit higher levels of MP contamination compared to other lakes (Su et al., 2016). A global study of 38 lakes revealed that 45% contained more than one plastic particle per cubic meter, with some of the most polluted lakes having over ten particles per cubic meter (Nava et al., 2023).

Research on MP in freshwater lakes, including studies in Lake Taihu (Su et al., 2016), has highlighted an increase in small-sized MP particles. These smaller MPs are particularly hazardous to aquatic species due to their higher surface area, which facilitates the adsorption and deposition of other contaminants (Devriese et al., 2017). Furthermore, the similarity between small-sized MP particles and zooplankton increases the likelihood of accidental ingestion by aquatic organisms. Autopsies of fish from the Lvsi fishery and wild fish from Poyang Lake, China, revealed significant amounts of small-sized MP in their bodies (Yuan et al., 2019). These findings underscore the growing concern about the ecological risks posed by small MPs in freshwater systems.

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Several lakes in China have been found to contain MP in various forms, with fibers being the most prevalent type. A statistical study revealed that fibers accounted for 49.6% of the MP detected in water samples (Handan et al., 2024). Debris, another common form of MP, was present in 16.2% of water samples from lakes and reservoirs, while films comprised 8.6% of the sediments and 9.3% of the water column. The majority of MP found in these lakes were secondary MPs, primarily resulting from the fragmentation of larger plastic debris. In contrast, spherical MPs, which were previously rare in Chinese lakes, primarily originated from primary sources. The source of MP directly influences their physical form: films are typically derived from plastic bags and packaging materials (Zhang et al., 2015), fragments result from the degradation and fragmentation of larger plastics (Fahrenfeld et al., 2019), and fibers primarily stem from textiles, fishing gear, and the washing of clothes (Browne, 2015).

The predominant polymer types found in the water columns of China's lakes and reservoirs include polyethylene (PE) (20.2%), polypropylene (PP) (20.1%), polyurethane (PU) (14.0%), and polyethylene terephthalate (PET) (12.7%). The wide range of polymer types reflects global plastic production demands, with polypropylene and polyethylene, which together account for 60% of global plastic production, being the most prevalent polymers. These materials are widely used in applications such as plastic bags, containers, food packaging, and pipes (Kye et al., 2023). Human activity is a significant factor influencing MP concentrations in lakes, as these particles originate from a variety of sources. MP entering lakes can be classified into two categories: direct and indirect sources (Dusaucy et al., 2021). Direct sources include tourism, agriculture, and fishing, while indirect sources refer to MP that enter lakes via surface runoff, sewage discharge, or atmospheric deposition. Although wastewater treatment facilities can eliminate most MP from domestic wastewater, many particles still make their way into the environment (Massoomeh et al., 2019). Additionally, MP removed during wastewater treatment are often retained in sludge, which can subsequently re-enter the water system through channels such as stormwater runoff. Agricultural runoff is another significant contributor, transporting MP from agricultural soils into lakes and reservoirs, with sewage irrigation, plastic films, and trellis covers being primary sources of MP in agricultural soils (Huang et al., 2020).

One of the key benefits of LDIR is its efficiency. The average analysis time per MP particle is approximately 8 seconds, significantly reducing detection time without compromising result accuracy (Whiting et al., 2022). Studies have demonstrated the versatile application of LDIR in diverse environmental contexts, including groundwater aquifers (Samandra et al., 2022), urban rivers (Fan et al., 2022), coastal zones (Scircle et al., 2020), atmospheric dust (Liu et al., 2022), agricultural soils (Li et al., 2021), and fish gastrointestinal systems (Lopez-Rosales et al., 2022). In this study, LDIR was employed for both qualitative and quantitative assessments of MP distribution properties in surface water. The system's capacity for rapid and autonomous characterization of polymer types and particle sizes positions LDIR as a critical tool for advancing MP pollution research and environmental monitoring strategies. The efficient detection and identification capabilities demonstrated by LDIR highlight its growing importance in addressing global environmental concerns related to plastic pollution.

The Pollution Load Index (PLI) is a significant quantitative measure used to assess the degree and danger of MP contamination across different environments, as well as serving as an internationally accepted method to assess pollution levels at varies sampling sites. Originally established by Tomlinson et al. in 1980 for the evaluation of metal contamination, it is now adapted for the assessment of MPs. The PLI elucidates the risk categories associated with MP contamination, often ranging from low to high risk. Aquatic ecosystems may suffer from the presence of MP and the associated risk levels. Greater PLI values have been correlated with negative impacts on the lives of animals and plants in impacted ecosystems (Davis & Selvaraju, 2023). Research has highlighted varying PLI results across different geographical locations, indicating that local environmental conditions and human activities significantly influence MP pollution levels (Haque et al.,2024). The PLI was reported to be less than 10 in Kumaraswamy Lake, with

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an average concentration of 8.77 ± 0.27 particles per liter across different seasons. The highest concentrations were observed during the monsoon season, particularly in areas near the lake's outlet, where values reached 10.70 ± 0.25 particles/L (Davis and Selvaraju, 2023).

Yuehai Lake is situated in a densely populated area, where urban activities contribute significantly to MP pollution. Studies indicate that MP concentrations are influenced by human activities such as tourism and local waste disposal practices. However, specific studies focusing on Yuehai Lake have not been conducted, which limits the understanding of how urbanization uniquely affects this lake's MP levels. At the same time, research on MP pollution in Yuehai Lake to evaluate the ecological risk assessment can provide valuable data for policymakers and environmental management authorities. The findings can contribute to the formulation of regulations and policies aimed at reducing plastic waste, improving waste management practices, and mitigating the release of MP into the environment. Additionally, the study can help raise awareness among stakeholders and promote sustainable practices to address the issue of MP pollution not only in Yuehai Lake but also in other similar freshwater ecosystems.

## EXPERIMENTAL DETAILS

### Study Area

Yuehai Lake, a component of the Yellow River system, is situated in Yinchuan, Ningxia, northwest of China. Renowned for its vastness and preservation of natural landforms, it stands as a significant feature in the western desert zone. The lakebed primarily comprises fine sand, silt, and clay particles, with minimal coarse sand or gravel. Its strategic location and diverse aquatic environments make it a key site for studying microplastic (MP) pollution dynamics in a freshwater desert lake ecosystem. To capture the variation in human activities and their potential influence on MP distribution, five distinct sampling sites were selected around Yuehai Lake, as shown in Figure 1.

Each site represents unique usage patterns and environmental pressures (Table 1). The Yuehai Fishing Base (S1) serves as the focal point for wild fishing activities, while Yuehai Skatepark (S2) hosts a bustling recreational hub with boating and other water-based entertainment. The business district of Yuhai Bay (S3) is characterized by large office complexes, whereas Sun Island (S4) is a serene residential zone with a small beach designed for children's recreation. The final site, Lijing Street (S5), experiences the highest traffic volume and is situated adjacent to a national highway, highlighting transportation-related environmental impacts. These carefully selected sites provide a comprehensive understanding of the relationship between human activities and MP pollution, offering valuable insights into the lake's environmental health and sustainability.

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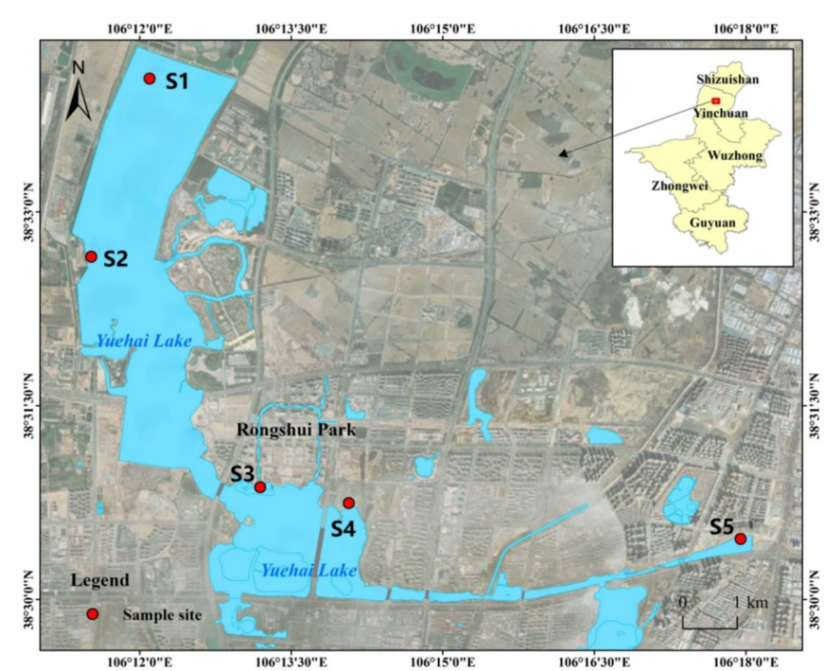


**Figure 1**. Map of sampling sites

Table 1. Information of sampling sites

| Points | Location | Coordinate | Main Activity |
|---|---|---|---|
| S1 | Yuehai Fishing Base | 38˚34'12''N,106˚12'22''E | Fishing |
| S2 | Yuehai Skatepark | 38˚32'58''N,106˚11'21''E | Entertainment |
| S3 | Yuhai Bay's business district | 38˚31'06''N,106˚13'18''E | Commerce |
| S4 | Sun Island | 38˚30'45''N,106˚14'02''E | Residence |
| S5 | Lijing Street | 38˚30'38''N,106˚17'55''E | Transportation |

**Sample Collection**

Surface water samples were collected using a Water Grab Sampler at each sampling site. The summarized methodology is shown in Figure 2. Water samples were collected from 0–45 cm below the water surface at each site using a stainless-steel sampler (with a 5L capacity and a 5m-long rope) that was cleaned with ultrapure water before each sampling (Saipolbahri et al., 2020). In order to analyze the MP, approximately 1L of the water sample was stored in a clean glass bottle. For replication purposes, 3 water samples were collected at each sampling site. The Water Grab Sampler was meticulously cleaned with deionized water at every sampling interval to minimize cross-contamination. All samples were collected and stored in glass bottles at 4˚C until they were sent to WEIPU Testing Technology Group Co., LTD (Shanghai, China) for MP detection.

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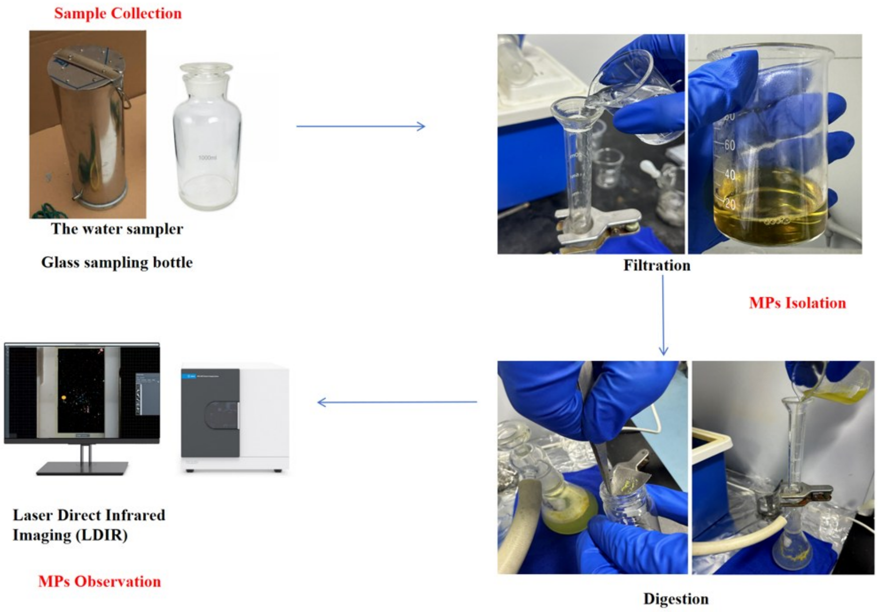


**Figure 2**. The flowchart of methods

## Isolation of MP

Water samples were weighed and vacuum-filtered through a 13 µm steel membrane, after which the membrane was placed inside a sanitized glass bottle. To remove organic matter, 30% hydrogen peroxide ($H_2O_2$) was added, allowing the solution to react completely for 2 hours. This was followed by a 10-minute ultrasonic sonication at room temperature to ensure thorough digestion. The digested solution was vacuum filtered again using a fresh 13 µm steel membrane.

To disperse the materials adhered to the membrane, the filter was fully submerged in a 95% ethanol solution and subjected to ultrasonic treatment for 30 minutes. Both sides of the membrane were washed repeatedly with ethanol to ensure complete transfer of particles. This process was repeated three times, with the glass bottle cleaned using ultrapure water between cycles to prevent contamination. The ethanol solution was then concentrated to 150 µL using a Basque dropper and drizzled onto high-reflective glass. After allowing the ethanol to fully evaporate, the sample was ready for Laser Direct Infrared (LDIR) spectroscopy analysis.

## Sorting and Identification of MP

The identification of MP was performed by using Laser Direct Infrared (LDIR) imaging spectrometer (8700 LDIR, Agilent, USA). The LDIR provides a comprehensive overview of all potential microplastic (MP) particles. The spectrometer scans a wave number range of 900–1800 cm−1 (Scircle et al., 2020). In 10 separate measurements, the average number of MP particles detected was 407, with a variance of less than 1%. This allowed for the identification and concentration of MP particles based on their quantity, shape, size, and surface characteristics. Data collection was performed using the default image analysis program, Agilent Clarity, and statistical analysis was conducted with Excel 2019. The data were then compared with the Agilent Spectrum Library's database of MP, with each particle assigned a corresponding

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matching degree. The degree of match between the spectra of specific particles and the standard spectra from the library ranged from 0 to 1. A high degree of correlation between the standard curve and the spectral curve indicated a higher probability of correctly identifying the specific type of MP.

A matching result is deemed acceptable when the LDIR system detects a particle's infrared spectrum with a matching degree greater than 0.65 in comparison to the reference spectrum in the MP library. Particles with a matching degree exceeding 80% are classified as definitive MP. Due to the machine's specifications and settings, the system can only identify particles within the wave number range of 20 to 500 µm. The system automatically categorizes particles into distinct size groups (20–100 µm and 100–500 µm). In our analysis, MP particles ranging from 20 to 100 µm were classified as small-sized MP, while those between 100 and 500 µm were categorized as large-sized MP. Using transmittance mode (300–400 particles per hour), the spectra of all particles were obtained and compared to a reference library for polymer identification.

**Pollution load index and polymeric and pollution risk assessments**

In order to determine the degree of contamination in aquatic systems, Tomlinson et al. (1980) introduced the MP pollution load index (PLI), which is computed using the MP abundance data. For comparing pollution levels across sites, the PLI is a standardized monitoring and assessment method. PLI >1 indicates that a site is polluted (Tomlinson et al., 1980). The PLI was determined in the following approach:

$$PLI_i = C_i / C_o \quad (1)$$

$$PLI_{lake} = \sqrt[n]{PLI_1 \times PLI_2 \times PLI_3 \times \ldots\ldots \times PLI_n} \quad (2)$$

where i stands for a sampling site, n for the total number of Yuehai Lake sampling sites, Ci for the MP abundance at sampling site I, and Co for the lowest baseline concentration derived from the literature. There is no background data in similar contexts and the analytical framework of this research, so the lowest abundance of MP identified in this study served as the baseline concentration. In the present scenario, $PLI_i$ indicates the pollution load index at sampling site i, while $PLI_{lake}$ signifies the lakeline MP pollution load index, computed by multiplying the square root of the total MP pollution load indices. The PLI values correspond to different hazard and risk category is shown in Table 2.

Table 2. Risk level criteria for MP pollution

| PLI | Hazard category | Risk category |
|---|---|---|
| <10 | I | Minor |
| 10-20 | II | High |
| 20-30 | III | Danger |
| >30 | IV | Extreme danger |

**Quality Assurance and Quality Control (QA/QC)**

To enhance data reliability and prevent external contamination, maintaining the integrity of sample collection and analysis is critical. This study adhered strictly to a plastic-free protocol for the collection, storage, processing, and analysis of all samples. Laboratory procedures were conducted in a controlled environment to minimize airborne contamination. A clean room or laminar flow hood was utilized to prevent external particles from entering the workspace, and samples were routinely covered with aluminum foil during processing to protect them from airborne contaminants. Researchers wore cotton laboratory coats and powder-free latex gloves to mitigate the risk of microfibers and other potential contaminants

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originating from clothing. Only glass or metal materials were used for sample collection and analysis, with all tools and equipment being triple-rinsed with ethanol prior to use. All solvents were filtered through a 0.45-µm PTFE membrane to remove potential contaminants. Negative controls (blank experiments) were employed to assess background contamination levels, while positive controls (spiked recovery experiments) ensured the proper functioning of the analytical methods. Comprehensive protocols for sample collection, handling, and analysis were developed to ensure the consistency and reproducibility of the experiments. These protocols included instrument calibration and the use of suitable reference materials.

## RESULTS AND DISCUSSION

### Abundance of MP

MP were detected in the surface water at all five sampling sites. The mean MP abundance was 907.47 ± 387.72 particles/L across all sites. Site S5 exhibited the highest MP abundance, with a mean value of 1472.33 ± 91.17 particles/L, followed by S1 (1134.33 ± 104.84), S2 (745.33 ± 14.25), S3 (648.67 ± 11.41), and S4 (536.67 ± 15.53) (Figure 3).

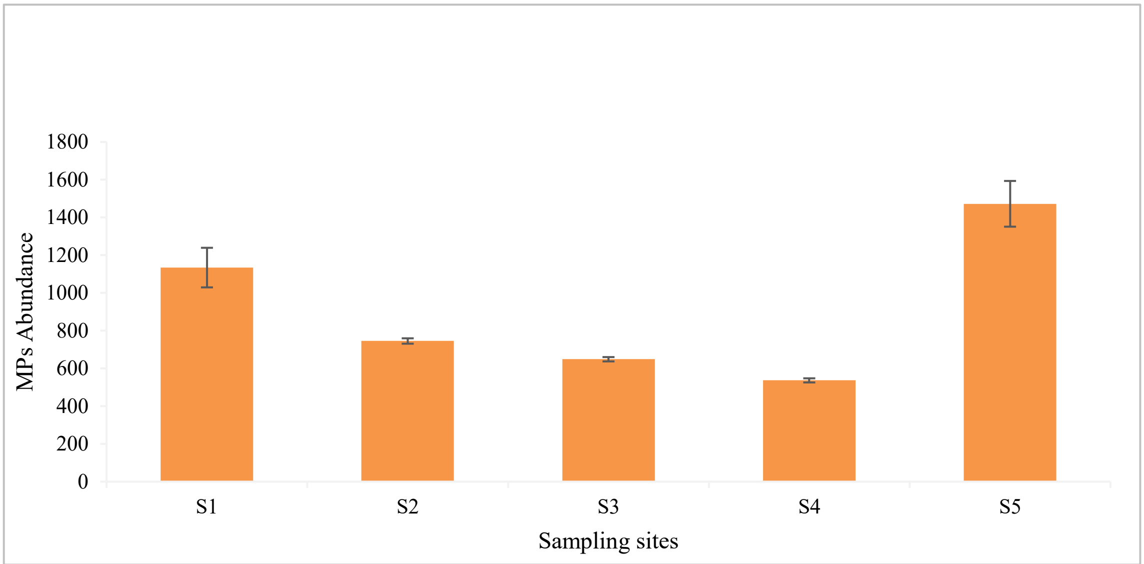


**Figure 3**. MP Abundance of five sampling sites

The MP abundances and distributions varied inconsistently across the sites. Higher MP abundances were observed at sites impacted by high transportation activity (S5) and fishing activities (S1). At site S5, the large volume of traffic and the presence of surrounding car factories likely contributed to the elevated MP levels. Tyre wear debris and plastic particles from industrial activities may be discharged into the lake via wind and rainfall runoff. Additionally, the slow current flow at S5 may have further contributed to the high MP concentration. Site S1, located near a fishing area, showed significant MP contamination due to the extensive use of plastic materials, such as fishing nets, ropes, and other fishing-related gear. Agricultural activities in the region also likely contributed to the presence of MP, as wind and hydrodynamic forces could facilitate the transportation of plastic debris into the lake.

In contrast, sites S2, S3, and S4, which were influenced by human activities such as food packaging, toiletries, and plastic waste from entertainment-related facilities, showed similar MP

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abundances. The higher MP concentration at S2 can be attributed to the presence of floating plastic recreational facilities, while S3 had a higher pedestrian traffic compared to S4, which may have contributed to the observed differences. These findings are consistent with those of previous studies. For instance, Xu (2024) found that MP pollution in Yangcheng Lake was closely associated with the fishing industry and tourism, reporting 514 MP particles, with 136 classified as small MPs (1.1–8.5 µm). Additionally, MP concentrations in lakes exhibit significant regional variation. For example, the average MP abundance in Yele Mallappa Shetty (YMS) Lake was 0.01 ± 0.0007 particles/$m^3$ (Kaviyarasi et al., 2024), while MP concentrations in Taihu Lake ranged from 1650 particles/$m^3$ to 9300 particles/$m^3$, with a mean value of 4482 particles/$m^3$ (Chen et al., 2024).

## Morphology of MP

The identified MPs in water samples were classified according to their shapes (Figure 4). Fragments (63.36%) were the most prevalent type of MP across all sampling sites, with proportions ranging from 51.28% to 67.19%. This was followed by fibers (33.22%) and films (3.42%). The distribution of MP shapes was relatively consistent across all sampling sites. The predominance of fragments in the studied areas is likely attributed to transportation and ongoing tourism activities. Additionally, plastics originating from fishing equipment, either used for catching fish or transporting goods, may also contribute to the high frequency of fragments. Fragments are particularly susceptible to suspension or floating in aquatic environments. In areas with low water flow, these particles are more likely to settle, whereas in regions with stronger currents, fragments may be re-suspended and dispersed over a larger area (Liu et al., 2019). Fragments are a major form of plastic and resin used in industrial manufacturing, particularly in the production and repair of automobiles. Furthermore, certain cosmetic and detergent particles, including exfoliating products, present significant challenges in terms of complete filtration during sewage treatment processes. Additionally, the degradation of automotive tyres, wear materials from urban environments, and polymer substances used in road markings can generate substantial quantities of fragments, which ultimately find their way into water bodies such as lakes (Liu et al., 2019).

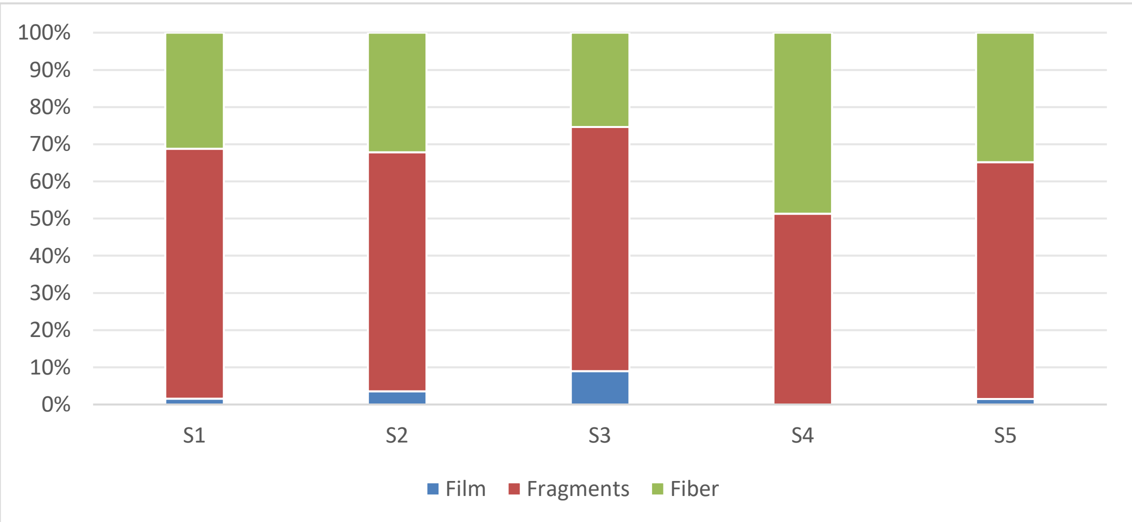


**Figure 4.** The proportion of different shapes of MP in sampling sites

## Chemical properties and dimension of MP

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LDIR analysis was used to identify the features, which included absorbance spectra and typical images of the observed MP polymer, such as polyamide (PA), polyethylene (PE), polyvinyl chloride (PVC) and polypropylene (PP) (Figure 5). The proportions of the summed relative abundance of each MP are shown in Figure 6. As a result, 17 MP polymer types were discovered in water samples. The results showed that fluororubber (FKM) (22.80%), fluorosilicone rubber (FVMQ) (16.90%), chlorinated polyethylene (CPE) (13.58%) and PVC (10.10%) were the dominant polymers, followed by Phenol-formaldehyde resin (PFR), Polytetrafluoroethylene (PTFE), PET, PU, Phenolic epoxy resin (PER), Polystyrene (PS), Acrylic copolymer (ACR), Styrene-butadiene-styrene (SBS), Polylactic acid (PLA), Acrylonitrile Butadiene Styrene (ABS), Polyoxymethylene (POM), Polymethylmethacrylate (PMMA) and PP which accounted for 6.55 %, 6.12 %, 4.89 %, 4.33%, 3.43%, 3.22%, 2.53%, 1.95%, 1.34%, 0.86%, 0.55%, 0.43%, 0.43% respectively.


**Figure 5**. Representative of MP infrared spectrogram detected by LDIR

FKM was the most common type of MP in this study. Of these, 456 particles were within the 20–100 um diameter range, and 21 particles were within the 100–500 um diameter range. FKM is extensively utilized in the automotive sector owing to its remarkable characteristics, notably its resistance to heat, chemicals, and oils. It is particularly effective for fuel seals, head and intake manifold gaskets, and other sealing applications that necessitate durability in the presence of high temperatures and aggressive fluids (Wang & Bai, 2016). The possible environmental effects of FKM (fluororubber) in lakes are mostly linked to the perfluorinated chemicals (PFASs) that it contains. These chemicals have remarkable chemical stability and are difficult to break down spontaneously. Research indicates that PFAS can disseminate across several mediums, including water and soil, and endure in the environment for extended periods, resulting in ongoing ecosystem contamination (Huang et al., 2024). The food chain influences fish and

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other aquatic species' growth, reproduction, and survival. PFASs that build up in marine species may be passed on through the food chain to predators like birds and mammals, which will affect the environment at higher levels of the food chain. Certain PFASs have been demonstrated to disrupt the endocrine system of fish, consequently impacting their reproductive capabilities and population viability (Shi et al., 2021). The accumulation of PFASs in lakes may result in eutrophication, causing algal blooms that subsequently impact the water's oxygen levels and aquatic species' viability (Huang et al., 2024).

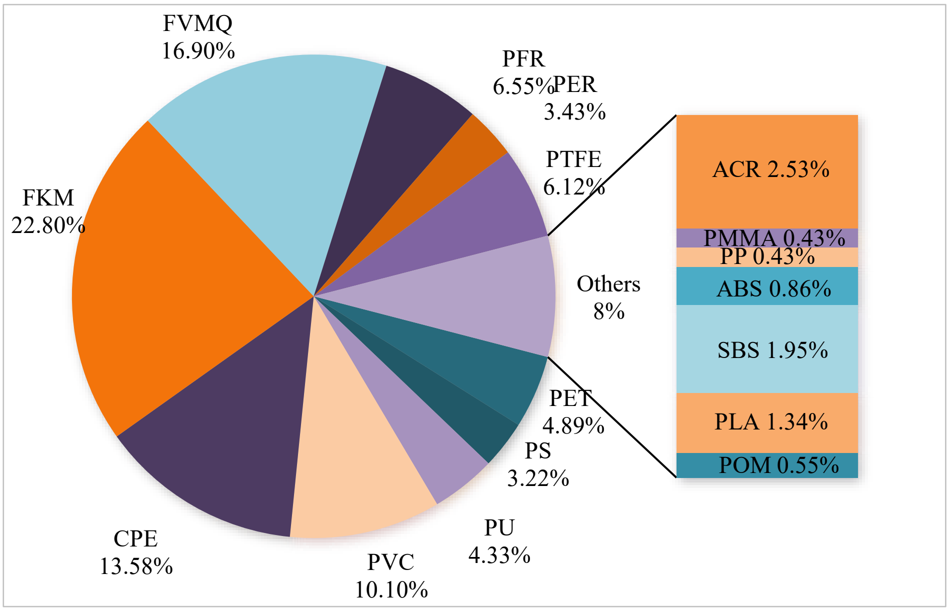


**Figure 6.** Types of MP polymer in water samples

FVMQ was the second leading MP type after FKM, with 342 particles (96.88%) of the analyzed particles in the diameter range of 20–100 um, and only 11 particles (3.12%) in the 100–500 um. As a high-performance elastomer, FVMQ combines the advantages of silicone rubber with enhanced chemical resistance due to its fluorinated makeup (Park et al., 2023). Followed by CPE, which is resistant to various chemicals, oils, heat, and environmental conditions, almost 99% of particles within the 20-100 um size range. CPE is a versatile synthetic polymer derived from the chlorination of polyethylene, characterized by a chlorine content ranging from 34% to 44%. Its unique composition imparts various properties, making it suitable for various applications across multiple industries (Bhagabati et al., 2015). PVC was detected as the fourth typical particle in water samples, and it is a versatile and widely used plastic material with a wide range of applications due to its desirable properties such as durability, chemical resistance, and low cost. It is commonly used for construction and building materials, packing and consumer goods, healthcare and medical devices and transportation (Lu et al., 2023).

The LDIR analysis conducted in this study identified MPs within the 20 to 500 µm diameter range. Further analysis revealed that over 90% of MP particles were between 20 and 100 µm in size, with the smallest measuring 20.34 µm and the largest 250.74 µm. Smaller MPs (20–100 µm) are more bioavailable due to their reduced size, which enhances their uptake by various aquatic organisms. Studies indicate that smaller MPs are more likely to be ingested by aquatic species due to their resemblance to natural food particles. This can result in significant physiological effects, including reduced food intake, developmental abnormalities, and behavioral changes (Issac & Kandasubramanian, 2021). Nearly all aquatic species are

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reported to ingest MPs to varying degrees, depending on species and environmental conditions (Wright et al., 2013). Ingestion of MPs can lead to digestive tract blockages, potentially resulting in mortality or impairing reproductive health (Kristanti et al., 2022). Moreover, MPs can undergo trophic transfer within the food chain, where smaller organisms ingest MPs, which are then consumed by larger predators, causing the accumulation of MPs at higher trophic levels (Lusher et al., 2017). This process raises concerns about the potential ecological and human health impacts associated with the consumption of contaminated aquatic food (Lee et al., 2023).

The MP polymer types and their abundance-based proportions differed among the different sites (Figure 7). Concerning their distributions, only ACR and CPE were discovered in all water samples. This may be because ACR and CPE are widely used in modifying and reinforcing PVC materials, whether it's fishing tackle and lines in fishing area, large amusement rides in entertainment area or plastic floats in a marina, or some plastic pipes at the bottom of a lake, which may be using these kinds of the material. The highest diversity of MP polymer types was identified in S1 (fishing area), with 15 types. Among them, PVC and CPE comprised about 50% of the total portions. S2 (entertainment area) and S3 (commerce area) had the common combinations and proportions of polymer types, which means FVMQ, CPE and PVC contributed substantial proportions. S4 (residence area) only had 4 polymer types but CPE accounted for over 70%, which indicated the MP pollution was concentrated. FKM has the largest proportion in S5 (transportation area), which is in line with its extensive use in the automotive industry.

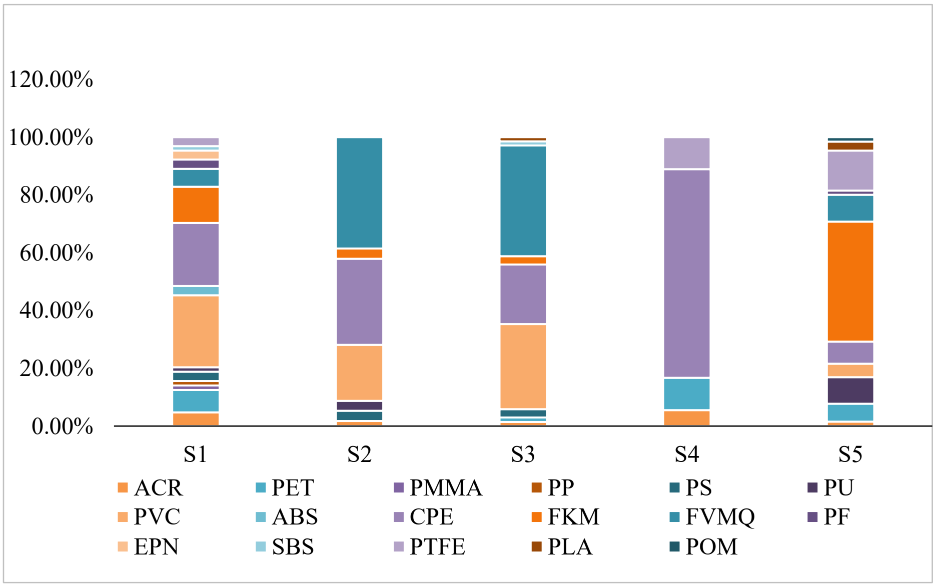


**Figure 7.** MP polymer types of each sampling site

## MP Pollution load index

The Pollution Load Index (PLI) results indicated that all sampling sites in Yuehai Lake were contaminated with microplastics (MP), as evidenced by PLI values greater than 1 (Table 3). Yuehai Lake itself exhibited a PLI of 4.57, categorizing it under risk class I. Site S5 demonstrated the highest PLI (12.91), suggesting that it experiences a significantly higher level of MP pollution compared to the other sites in the study area. This elevated pollution load can likely be attributed to the abundance of MPs, as the PLI is strongly correlated with their concentration. These findings are consistent with the PLI values observed in Nikli Lake, Kishoreganj, Bangladesh, where PLI values ranged from 1 to 2, indicating moderate MP

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contamination (Islam et al., 2024). Conversely, a study conducted at Kumaraswamy Lake, Coimbatore, reported slight MP pollution (PLI < 10), with MPs also categorized under risk class I (Davis & Selvaraju, 2023).

The results of this study provide valuable insights for policymakers in implementing more stringent regulations regarding MP pollution within the region. Given the elevated pollution levels at S5, it is recommended that a vegetated buffer zone be established between the road and the lake to capture and filter MPs from the runoff. Additionally, the installation of baffles or filters on both sides of the road could help trap larger plastic particles and MPs before they enter the lake. A regular monitoring system should also be instituted to track MP concentrations in both the streets and the lake. These measures would serve as effective strategies to mitigate the MP pollution problem.

Table 3. The PLI Value of every site and the lake

| Sites | S1 | S2 | S3 | S4 | S5 | Yuehai Lake |
|---|---|---|---|---|---|---|
| PLI Value | 9.90 | 6.19 | 5.78 | 1 | 12.91 | 4.57 |

## CONCLUSION

This study identified significant microplastic (MP) contamination in the surface water of Yuehai Lake, with variations in the quantity, types, and shapes of MPs, predominantly in the 20–100 µm size range. The prevalent polymers, FKM and polyvinyl chloride (PVC), are known for their persistence and resistance to degradation, contributing to long-term accumulation in aquatic ecosystems. Understanding the specific polymers present is crucial for predicting MP pollution's long-term ecological and health impacts, as different polymers require tailored waste management strategies and recycling processes.To mitigate MP pollution, upgrading sewage treatment technologies, developing filtration systems, implementing biodegradable packaging, and enacting stricter plastic use regulations are urgently needed. Public awareness campaigns and voluntary industry initiatives to adopt eco-friendly practices will further support pollution reduction. Future research should implement year-round sampling to capture seasonal variations in MP pollution and correlate findings with meteorological and hydrological variables such as precipitation and water flow. Monitoring land-based MP inputs and tracking polymer degradation under diverse environmental conditions will provide insights into long-term accumulation patterns. Additionally, integrating sediment and biota analyses will reveal temporal changes in MP bioavailability and ecosystem impacts. These approaches will enhance understanding of MP pollution dynamics and inform targeted management strategies for Yuehai Lake.

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### Conflict of interest statement

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

### Authors' contributions

Ren Jia carried out the research and wrote the article. Faeiza Buyong conceptualised the central research idea and provided the theoretical framework. Faeiza Buyong and Huifang Yang designed the research, supervised research progress; Faeiza Buyong anchored the review, revisions and approved the article submission.

## REFERENCES

https://doi.org/10.24191/scl.v19i2.6907

Anderson, P. J., Warrack, S., Langen, V., Challis, J. K., Hanson, M. L., Rennie, M. D. (2017) Microplastic contamination in Lake Winnipeg, Canada. *Environmental Pollution*. 225, 223–231.

Bhagabati, P., Chaki, T. K., & Khastgir, D. (2015).Chlorinated polyethylene (CPE)/ethylene methacrylate copolymer (EMA)/sepiolite nanocomposite via a facile one-step covalent modification technique. *RSC Advances*, 5(74). https://doi.org/10.1039/c5ra06488k

Browne, M. A. (2015). Sources and pathways of microplastics to habitats. *Marine Anthropogenic Litter*. https://doi.org/10.1007/978-3-319-16510-39

Browne, M. A., Crump, P., Niven, S. J., Teuten, E., Tonkin, A., Galloway, T., & Thompson, R. (2011). Accumulation of microplastics on shorelines worldwide: Sources and sinks. *Environmental Science and Technology*, 45(21). https://doi.org/10.1021/es201811s

Chen, H. W., Qin, Y. H., Huang, H., Xu, W. Y. (2020). A Regional Difference Analysis of Microplastic Pollution in Global Freshwater Bodies Based on a Regression Model. *Water*, 12(7):1889-. https://doi.org/ 10.3390/W12071889

Chen, L., Zhou, S. L., Su, B., Qiu, Y. F., Li, Y.(2024) Microplastic pollution in Taihu Lake: Spatial distribution from the lake inlet to the lake centre and vertical stratification in the water column, *Environmental Pollution* (363), https://doi.org/10.1016/j.envpol.2024.125102.

Davis, E., Selvaraju, R. (2023).Characterization of microplastics and its Pollution load index in freshwater Kumaraswamy Lake of Coimbatore, India. https://doi.org/10.21203/rs.3.rs-2610640/v1

Devriese, L. I., De Witte, B., Vethaak, A. D., Hostens, K., & Leslie, H. A. (2017). Bioaccumulation of PCBs from microplastics in Norway lobster (Nephrops norvegicus): An experimental study. *Chemosphere*, 186. https://doi.org/10.1016/j.chemosphere.2017.07.121

Ding, L., Mao, R., Fan, Guo, X., Yang, X., Zhang, Q., & Yang, C. (2019). Microplastics in surface waters and sediments of the Wei River, in the northwest of China. *Science of the Total Environment*, p. 667. https://doi.org/10.1016/j.scitotenv.2019.02.332

Dusaucy, J., Gateuille, D., Perrette, Y., & Naffrechoux, E. (2021). Microplastics pollution of worldwide lakes. *Environmental Pollution* (Vol. 284). https://doi.org/10.1016/j.envpol.2021.117075

Fahrenfeld, N. L., Arbuckle-Keil, G., Naderi Beni, N., & Bartelt-Hunt, S. L. (2019). Source tracking microplastics in the freshwater environment. *TrAC - Trends in Analytical Chemistry* (Vol. 112). https://doi.org/10.1016/j.trac.2018.11.030

Fan, Y., Zheng, J., Deng, L., Rao, W., Zhang, Q., Liu, T., Qian, X.(2022). Spatiotemporal dynamics of microplastics in an urban river network area. *Water Res*. https://doi.org/10.1016/j.watres.2022.118116

Granados-Sánchez, R. R., Sedeño-Díaz, J. E., López-López, E. (2024). Microplastic pollution and associated trace metals in freshwater ecosystems within protected natural areas: the case of a biosphere reserve in Mexico.*Environmental Science*, 12. https://doi.org/10.3389/fenvs.2024.1441340

Guo, Y. S., Li, J. H.(2020) Study on plastic waste import management policies of typical countries in the Asian-Pacific region. *World Environment* (Vol 3).

Handan, H., Shaoxi, C., Siyuan, C., Qiang, L., Pengwei, W., Rumeng, Y., Xiaoyi, Z., Bei, Y., Yanli, J., Tingting, C., Yunchao, L., Jing, H., Run, L., Qi, C., Fang, Y., Lihua, P., Yunru, C., Weihua, H., Pan, Y., Gaozhong, P., Jianzhi, Z., Xingjun, T. (2024). Spatial and Temporal Distribution Characteristics and Potential Sources of Microplastic Pollution, *China's Freshwater Environments. Water*, 16(9):1270-1270. https://doi.org/10.3390/w16091270

Haque, A., Holsen, T. M. & Baki, A. B. M. (2024) Distribution and risk assessment of microplastic pollution in a rural river system near a wastewater treatment plant, hydro-dam, and river confluence. https://doi.org/10.1038/s41598-024-56730-x

Huang, L. Q., Wang, W. R., Zhang, Y. T., Xu, Y. C., Wang, X. H., Yu, X. R., Chen, S., Gu, C., Chen, Z. H. (2024) Research progress on the pollution status of per-and polyfluoroalkyl substances (PFASs) in surface water: A review. *Environmental Chemistry*, 43(3): 693-710. https://doi.org/10.7524/j.issn.0254-6108.2022090901

https://doi.org/10.24191/scl.v19i2.6907

Huang, Y., Liu, Q., Jia, W., Yan, C., & Wang, J. (2020). Agricultural plastic mulching is a source of microplastics in the terrestrial environment. *Environmental Pollution*, 260. https://doi.org/10.1016/j.envpol.2020.114096

Islam, A. R. M. T., Hasan, M., Sadia, M. R., Mubin, A. N., Ali, M. M., Senapathi, V., Idris, A. M., & Malafaia, G. (2024). Unveiling microplastics pollution in a subtropical rural recreational lake: A novel insight. *Environmental Research*, 250. https://doi.org/10.1016/j.envres.2024.118543

Issac, M. N., Kandasubramanian, B. (2021) Effect of microplastics in water and aquatic systems. *Environ Sci Pollut Res*. Apr;28(16):19544-19562. https://doi.org/10.1007/s11356-021-13184-2.

Jones, N. R., Alix, M., Jersey, D., Jennifer, L., Thomas L., Rodemann, J., Rivers-Auty. (2023). Identifying laboratory sources of microplastic and nanoplastic contamination from the air, water, and consumables. *Journal of Hazardous Materials*, 465:133276-133276. https://doi.org/10.1016/j.jhazmat.2023.133276

Kamaruddin, S. A., Rusli, H. H., Abd. A., Khairul, N. & Roslani, M. A. (2020). Characteristics and distribution of microplastics in surface sediment of Selat Pulau Tuba, Langkawi, Kedah. *Malaysian Journal of Sustainable Environment*, 7 (2). pp. 139-160.

Kaviyarasi, N. S., Lakshmi, V., Prasanna, S., Abass, A., Anifowoshe, T. (2024). Microplastic pollution in the surface water of Yele Mallappa Shetty Lake, Bengaluru: first report. *Journal of Environmental Biology*, 45(5):515-524. https://doi.org/10.22438/jeb/45/5/mrn-5217

Koelmans, A. A., Bakir, A., Burton, G. A., Janssen, C. R. (2016) Microplastic as a Vector for Chemicals in the Aquatic Environment: Critical Review and Model-Supported Reinterpretation of Empirical Studies. *Environ Sci Technol*. Apr 5;50(7):3315-26. https://doi.org/10.1021/acs.est.5b06069

Kristanti, R. A., Wong, W. L., Darmayati, Y., Hatmanti, A., Wulandari, N. F., Sibero, M. T., Afianti, N. F., Hernandes, E., & Lopez-Martinez, F. (2022) Characteristics of Microplastic in Commercial Aquatic Organisms. *Tropical Aquatic and Soil Pollution*, 2(2), 134–158. https://doi.org/10.53623/tasp.v2i2.134

Kye, H., Kim, J., Ju, S., Lee, J., Lim, C., & Yoon, Y. (2023). Microplastics in water systems: A review of their impacts on the environment and their potential hazards. *Heliyon* (Vol. 9, Issue 3). https://doi.org/10.1016/j.heliyon.2023.e14359

Lee, Y., Cho, J., Sohn, J., Kim, C.(2023) Health Effects of Microplastic Exposures: Current Issues and Perspectives in South Korea. *Yonsei Med J*. May; 64(5):301-308. https://doi.org/10.3349/ymj.2023.0048.

Li, C., Busquets, R., & Campos, L. C. (2020). Assessment of microplastics in freshwater systems: A review.*Science of the Total Environment* (Vol. 707). https://doi.org/10.1016/j.scitotenv.2019.135578

Li, J., Liu, H., & Paul Chen, J. (2018). Microplastics in freshwater systems: A review on occurrence, environmental effects, and methods for microplastics detection. *Water Research* (Vol. 137). https://doi.org/10.1016/j.watres.2017.12.056

Li, Q., Zeng, A., Jiang, X., Gu, X. (2021). Are microplastics correlated to phthalates in facility agriculture soil? *Hazard. Mater.* 412. https://doi.org/10.1016/j.jhazmat.2021.125164

Liu, N. N, Cheng, S. K., Wang, X. M., et al. (2022).Characterization of microplastics in the septic tank via laser direct infrared spectroscopy. *Water Research*，2022，226：119293. https://doi.org/10.1016/j.watres.2022.119293

Liu, P., Shao, L., Li, Y., Jones, T., Cao, Y., Yang, C. X., Zhang, M., Santosh, M., Feng, X., BeruBe, K. (2022). Microplastic atmospheric dustfall pollution in urban environment: evidence from the types, distribution, and probable sources in Beijing, China. *Sci. Total Environ*. https://doi.org/10.1016/j.scitotenv.2022.155989

Liu, S. S, Fu, J. P., Guo, C. L., et al. Research progress on environmental behavior and ecological toxicity of microplastics. *Journal of Agro-Environment Science*, 2019, 38(5): 957-969.

Lopez-Rosales, A., Andrade, J., Fernandez-Gonzalez, V., Lopez-Mahia, P., Muniategui Lorenzo, S.(2022). A reliable method for the isolation and characterization of microplastics in fish gastrointestinal tracts using an infrared tunable quantum cascade laser system. *Mar. Pollut. Bull*. 178. https://doi.org/10.1016/j.marpolbul.2022.113591

https://doi.org/10.24191/scl.v19i2.6907

Lu, L., Li, W., Cheng, Y., & Liu, M. (2023). Chemical recycling technologies for PVC waste and PVC-containing plastic waste: A review. *Waste Management*, 166. https://doi.org/10.1016/j.wasman.2023.05.012

Lu, X., Li, J. H., Weng, Y. X., Nie, Y. F. (2002) PVC wastes and their treatment. *Techniques and Equipment for Environmental Pollution Control*.Vol . 3 , No . 9

Luo, W. K., Fu, H. Y, Lu, Q. Y., Li, B., Cao, X., Chen, S. F., Liu, R. J., Tang, B., Yan, X., Jing, Z. (2024). Microplastic pollution differences in freshwater river according to stream order: Insights from spatial distribution, annual load, and ecological assessment. *Journal of Environmental Management*, 366:121836-121836. https://doi.org/10.1016/j.jenvman.2024.121836

Lusher, A. L., Hollman, P. C. H., Mendoza-Hill, J. J. (2017). Microplastics in fisheries and aquaculture: status of knowledge on their occurrence and implications for aquatic organisms and food safety. *FAO Fisheries and Aquaculture Technical Paper.* No. 615. Rome, Italy

Ma, Z. F., Niu, G. Q., & Lu, S. (2023). China Plastic Processing Industry. *China Plastic*, 37(5), 110–115.

Massoomeh, H., Aldrin, A. & Javad, M.T. (2019).The Impact of the Physical Environment on Residents' Self-rated Health: A Case Study in Penang, Malaysia. *Malaysian Journal of Sustainable Environment*, 6 (1). pp. 109–127.

Nava, V., Chandra, S., Aherne, J. et al. (2023). Plastic debris in lakes and reservoirs. Nature 619, 317–322 (2023). https://doi.org/10.1038/s41586-023-06168-4

Park, Y. W., Yoon, J. H., Shin, K. H., Cho, Y. J., Yun, J. H., Han, W. H., Hong, M. H., Kang, D. G., & Kim, H. Y. (2023). Enhancing Stiffness and Oil Resistance of Fluorosilicone Rubber Composites through Untreated Cellulose Reinforcement. *Polymers*, 15(23). https://doi.org/10.3390/polym15234489

Peng, G., Zhu, B., Yang, D., Su, L., Shi, H., & Li, D. (2017). Microplastics in sediments of the Changjiang Estuary, China. *Environmental Pollution*, 225. https://doi.org/10.1016/j.envpol.2016.12.064

Plastics Europe Market Research Group. (2018). Plastics -The Facts 2018. Plastics Europe.

Pramanik, P. (2024, September 22). Microplastics are everywhere! Scientists call for swift global action. News Medical Life Sciences. https://www.news-medical.net/news/20240922/Microplastics-are-everywhere!-Scientists-call-for-swift-global-action.aspx

Saipolbahri, N., Anak Bitlus, M. L., Ismail, N. A., Fauzi, N. M., & Subki, N. S. (2020). Determination of microplastics in Surface Water and Sediment of Kelantan Bay. Earth and *Environmental Science*, 549(1). https://doi.org/10.1088/1755-1315/549/1/012059

Samandra, S., Johnston, J. M., Jaeger, J. E., Symons, B., Xie, S., Currell, M., Ellis, A. V., Clarke, B.O.(2022). Microplastic contamination of an unconfined groundwater aquifer in Victoria, Australia. *Sci. Total Environ*. 802, 149727. https://doi.org/10.1016/j.scitotenv.2021.149727

Scircle, A., Cizdziel, J. V., Tisinger, L., Anumol, T., Robey, D.(2020). Occurrence of microplastic pollution at oyster reefs and other coastal sites in the mississippi sound, USA: impacts of freshwater inflows from flooding. *Toxics* 8 (2). https://doi.org/10.3390/toxics8020035

Scherer, C., Weber, A., Stock, F., Vurusic, S., Egerci, H., Kochleus, C., Arendt, N., Foeldi, C., Dierkes, G., Wagner, M., Brennholt, N., & Reifferscheid, G. (2020). Comparative assessment of microplastics in water and sediment of a large European river. *Science of the Total Environment*, 738. https://doi.org/10.1016/j.scitotenv.2020.139866

Scircle, A., Cizdziel, J. V., Missling, K., Li, L., & Vianello, A. (2020). Single-Pot Method for the Collection and Preparation of Natural Water for microplastics Analyses: Microplastics in the Mississippi River System during and after Historic Flooding. *Environmental Toxicology and Chemistry*, 39(5). https://doi.org/10.1002/etc.4698

Sighicelli, M., Pietrelli, L., Lecce, F., Iannilli, V., Falconieri, M., Coscia, L., Di Vito, S., Nuglio, S., Zampetti, G. (2018) Microplastic pollution in the surface waters of Italian Subalpine Lakes. *Environ. Pollut.* 236, 645–651.

Su, L., Xue, Y., Li, L., Yang, D., Kolandhasamy, P., Li, D., & Shi, H. (2016). Microplastics in Taihu Lake, China. *Environmental Pollution*, 216. https://doi.org/10.1016/j.envpol.2016.06.036

https://doi.org/10.24191/scl.v19i2.6907

Shi, R., Mao, R. Y., Zhang, M., LÜ Y. L., Song, S., Zhao, J. X. (2021) Distribution, Sources, and Ecological Risks of Polyfluoroalkyl Substances in the Surface Water of the Wuliangsuhai Watershed. *Environmental Science*, 42(2): 663-672.

Shruti, V. C., Kutralam-Muniasamy, G. (2023). Blanks and bias in microplastic research: Implications for future quality assurance. *Trends in Environmental Analytical Chemistry*, 38:e00203-e00203. https://doi.org/10.1016/j.teac.2023.e00203

Tomlinson, D. L., Wilson, J. G., Harris, C. R., Jeffrey, D. W., 1980. Problems in the assessment of heavy metal levels in estuaries and the formation of a pollution index. *Helgoländer Meeresun*. 33, 566–575. https://doi.org/10.1007/BF02414780

Wang, W., Yuan, W., Chen, Y., & Wang, J. (2018). Microplastics in surface waters of Dongting Lake and Hong Lake, China. *Science of the Total Environment*, 633. https://doi.org/10.1016/j.scitotenv.2018.03.211

Wang, Y., & Bai, Y. (2016). The functionalization of fluoroelastomers: Approaches, properties, and applications. *RSC Advances* (Vol. 6, Issue 59). https://doi.org/10.1039/c6ra05816g

Whiting, Q. T., O'Connor, K. F., Potter, P. M., Al-Abed, S. R. A high-throughput, automated technique for microplastics detection, quantification, and characterization in surface waters using laser direct infrared spectroscopy. *Anal Bioanal Chem*. 2022 Dec;414(29-30):8353-8364. https://doi.org/10.1007/s00216-022-04371-2.

Wright, S. L., Thompson, R. C., Galloway, T. S. (2013) The physical impacts of microplastics on marine organisms: a review. *Environmental Pollution*. Jul;178:483-92. https://doi.org/10.1016/j.envpol.2013.02.031.

Xu, C., Zhang, B., Gu, C., Shen, C., Yin, S., Aamir, M., & Li, F. (2020). Are we underestimating the sources of microplastics pollution in terrestrial environments? *Journal of Hazardous Materials* (Vol. 400). https://doi.org/10.1016/j.jhazmat.2020.123228

Yang, Y., Xie, E., Du, Z., Peng, Z., Han, Z., Li, L., Zhao, R., Qin, Y., Xue, M., Li, F., Hua, K., & Yang, X. (2023). Detection of Various microplastics in Patients Undergoing Cardiac Surgery. *Environmental Science and Technology*, 57(30), 10911–10918. https://doi.org/10.1021/acs.est.2c07179

Yıldırım. G., Anindita, M., Pan, X., Rahman,S., Alim, M. A., Rehana, S., Rahman, A. (2024). Bibliometric Insights into Microplastic Pollution in Freshwater Ecosystems. *Water*, 16(22):3237-3237. https://doi.org/10.3390/w16223237

Yuan, W., Liu, X., Wang, W., Di, M., & Wang, J. (2019). Microplastics abundance, distribution and composition in water, sediments, and wild fish from Poyang Lake, China. *Ecotoxicology and Environmental Safety*, 170. https://doi.org/10.1016/j.ecoenv.2018.11.126

Zbyszewski, M., Corcoran, P. L. Distribution and degradation of fresh water plastic particles along the beaches of Lake Huron, Canada. *Water Air Soil Pollut*. 2011, 220, 365–372.

Zhang, B., & Cheng, X. W. (2017). Comparison of Plastic Generation and Import/Export in Europe, America and China. *Renewable Resources and Circular Economy*, 10(9), 39–44.

Zhang, K., Gong, W., Lv, J., Xiong, X., & Wu, C. (2015). Accumulation of floating microplastics behind the Three Gorges Dam. *Environmental Pollution*, p. 204. https://doi.org/10.1016/j.envpol.2015.04.023

Zhang, Y., Kang, S., Allen, S., Allen, D., Gao, T., & Sillanpää, M. (2020). Atmospheric microplastics: A review on current status and perspectives. *Earth-Science Reviews* (Vol. 203). https://doi.org/10.1016/j.earscirev.2020.103118

Zhang, Z., Zulpiya, M., & Chen, Y. (2020). Current research and perspective of microplastics (MP) in soils (dust), rivers (lakes), and marine environments in China. *Ecotoxicology and Environmental Safety* (Vol. 202). https://doi.org/10.1016/j.ecoenv.2020.110976

https://doi.org/10.24191/scl.v19i2.6907