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Review

Data Mining Revealing Recent Microplastics Pollution of Freshwater in China

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Abstract: This review mainly discusses the characteristics and correlation of microplastics (MPs) in freshwater systems under various geographical environments in China. The distribution and source of MPs are analyzed and their spatial analyses are performed using the GIS method. Besides, the current and future situation of microplastic pollution in China is further evaluated through data mining. Results indicate that recent studies mainly focused on the middle and lower reaches of the yangtze river and its tributaries, as well as lakes and reservoirs along the yangtze river. Notably, large-scale reservoirs, rivers, and lakes located in densely populated areas showed higher abundances of MPs. Taken together, the current MP's pollution of freshwater in China was not optimistic. Novel technologies should be developed to remove existing microplastics and new laws and regulations should be promulgated to reduce plastic waste pollution.

Keywords: Microplastics, MPs, GIS, Freshwater, Spatial Analysis

Introduction

Nowadays, plastics had been used globally due to their excellent properties, such as versatility, durability, and good adaptability (Tang *et al*., 2021). The plastic debris would further fragment into small plastic pieces *via* physical abrasion, chemical interaction, and biological erosion (Kabir *et al*., 2021). The ubiquity of microplastics (MPs, plastic particles <5 mm, including nanosized plastics <1 m) in the global biosphere raises increasing concerns about their implications for human health. Recent evidence indicates that humans constantly inhale and ingest MPs; however, whether these contaminants pose a substantial risk to human health is far from understood. The lack of crucial data on exposure and hazard needs to be addressed (Vethaak and Legler, 2021). Many studies had been conducted to observe the occurrence of microplastic pollution in some natural environments, such as oceans, freshwater, sediments, soils, groundwater, wetlands, and the atmosphere (Chen *et al*., 2020; Eerkes-Medrano *et al*., 2015; Forero-Lopez *et al*., 2021; Huang *et al*., 2021a; Jiang *et al*., 2022; Kumar *et al*., 2021; Xu *et al*., 2020; Ya *et al*., 2021). Among them, research on freshwater has drawn prevailing attention in recent years, because freshwater is more closely related to human activities (Vivekanand *et al*., 2021).

China was one of the largest plastics producing and consuming countries, and MP's pollution in the Chinese freshwater systems had gained significant attention. The associated publications had grown rapidly in the past five years (Fu *et al*., 2020). China plays an important role in global plastic production, consumption, and treatment. Most studies focus on a certain water body, and few studies discuss the characteristics of MPs pollution in the whole freshwater system nationwide. Currently, China's research on MPs is mainly concentrated in the middle and lower reaches of the yangtze river and its tributaries, lakes, and reservoirs along the yangtze river. The research area is usually located in densely populated areas, and the MPs abundance of large reservoirs, rivers, and lakes is usually high. MPs in surface water and sediments in China are mainly composed of polyethylene and polypropylene, and the most common forms (fibers and fragments). The source-sink-pathway model will help to further identify the migration of MPs from sources to freshwater systems.

Risk to Human Health

Recent epidemiological studies showed that exposure to MPs could disrupt human immune function and lead to autoimmune diseases or immunosuppression (Rahman *et al*., 2021). The final targeted and accumulated organ of MPs is the gut (Wick *et al*., 2010). MPs often enter the body through the stratum corneum and combine with numerous

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target cells to interfere with immune processes (Wick *et al*., 2010; Yee *et al*., 2021). Numerous in vitro and in vivo studies had also reported the acute toxicological effects of MPs on the human body, such as physical stress and injury, apoptosis, necrosis, inflammation, oxidative stress, and immune response. Such persistent effects could even induce cancer (dos Santos *et al*., 2011). Besides, MPs could absorb various environmental pollutants (such as heavy metals and hydrophobic organic pollutants) and release plastic additives, which might produce joint toxic effects (Huang *et al*., 2021a, b).

Humans would be exposed to these MPs through the ingestion of contaminated freshwater and food, inhalation, personal care products, textiles, or indoor dust. A study indicated that people who drank only bottled water indirectly consumed 90000 MPs particles, and those who drank only tap water without any plastic products consumed 4000 particles. Therefore, people should try to avoid using plastic bottles to drink fresh water (Cox *et al*., 2019). In addition, MPs had been found in many foods and condiments, such as bivalves, fish, and other seafood (Bessa *et al*., 2018; Karbalaei *et al*., 2018; Li *et al*., 2016; Mathalon and Hill, 2014; Naji *et al*., 2018; Neves *et al*., 2015), sugar, and salt (Karami *et al*., 2017; Liebezeit and Liebezeit, 2013). It was predicted that the MPs consumed by table salt in Europe are 37 MPs (1-10 MPs/kg of salt) particles per person every year (Karami *et al*., 2017). Another report showed that this figure in China was much higher (100 particles per person) (Yang *et al*., 2015). Therefore, it has become an important issue to pay attention to the MPs in the Chinese freshwater environment.

Current Situation of Global MPs in Freshwater

Recent studies had shown that freshwater ecosystems and biodiversity were threatened by microplastic pollution in Africa (Reynolds and Ryan, 2018). This also indicates that the freshwater sector is threatened by microplastic pollution. The MPs in freshwater were mainly due to the scouring of larger plastics through water flow. Under the action of mechanical force, they are first decomposed into smaller MPs, and then decomposed into smaller plastics *via* ultraviolet exposure and biological degradation (Oliveira and Almeida, 2019). These smaller MPs in the freshwater will pose greater health risks (Lei *et al*., 2018). The total amount of MPs is significantly positively correlated with the population. Besides, the concentration of MPs was still affected by the surrounding industrial structure, but this impact is often difficult to quantify. Moreover, various research groups carried out many studies on freshwater rivers in China, but the results are not optimistic (Gewert *et al*., 2015; Niaounakis, 2017).

Currently, the studies on freshwater MPs in China had carried out for a long time (Zhao *et al*., 2022), including lakes, freshwater rivers, and reservoirs. A recent study analyzed the MPs in freshwater in the yangtze river Basin (Zhang *et al*., 2021), and another study investigated the distribution and characteristics of MPs in the backwater area of xiangxi river, a typical tributary of the Three Gorges reservoir (Zhang *et al*., 2017). More studies had even conducted MPs surveys in deep inland areas, including ulansuhai in Inner Mongolia (Wang *et al*., 2019) and the tibetan plateau river (Feng *et al*., 2020), indicating the existence of MPs in inland rivers. More studies are concentrated on coastal areas from the estuary of the yellow river in the north (Han *et al*., 2020) to the estuary of Shenzhen (Yan *et al*., 2019). All results showed that MPs exist widely in almost all freshwater in China.

Analysis of the Current Situation of MPs in China

MPs distribution in surface water presented obviously regional differences in abundance (Fig. 1). Compared with other countries, MP pollution in the river system in China was at a medium-to-high level nationwide (Zhao *et al*., 2022). The minimum content of MPs in Qin River was as low as 0.1 items/m^3 and that in the yulin river was 0.013 items/L, whereas the maximum concentration of MPs up to 53250 items/m^3 was observed in Pearl River and 930 items/L in lower yellow river near the estuary (Han *et al*., 2020; Mao *et al*., 2020; Yan *et al*., 2019). Those studies on the occurrence of freshwater MPs have mainly focused on the yangtze river (Mao *et al*., 2021).

From China's coastline, the concentration of MPs gradually decreases from north to south in general (Fig. 1). Among them, the concentration of MPs in the estuary of the yellow river was much higher than that in other areas (Han *et al*., 2020). Secondly, the concentration of MPs in economically developed regions was also very high. For example, the concentration of MPs in Taihu (Jiangsu) (Su *et al*., 2016) and Shenzhen (Yan *et al*., 2019) was higher than that in neighboring regions.

Besides the coastal areas, the provinces and cities along the yangtze river had also carried out much research on MPs. Moreover, in reservoirs and lakes, the content of MPs was higher, such as in the danjiangkou reservoir (Di *et al*., 2019; Lin *et al*., 2021) and Poyang Lake (Yuan *et al*., 2019). Because of different densities, buoyancy, and adsorption capacity, MPs can affect their migration, transportation, and falling capacity and further affect the distribution in surface water. In areas where water collects, MPs were also more likely to accumulate. The abundance of MPs in the maozhou river was lower in the wet season than that in the dry season, due to rainfall increased river flow and decreased the content of MPs (Wu *et al*., 2020), implying that the flow size was an important factor in freshwater.

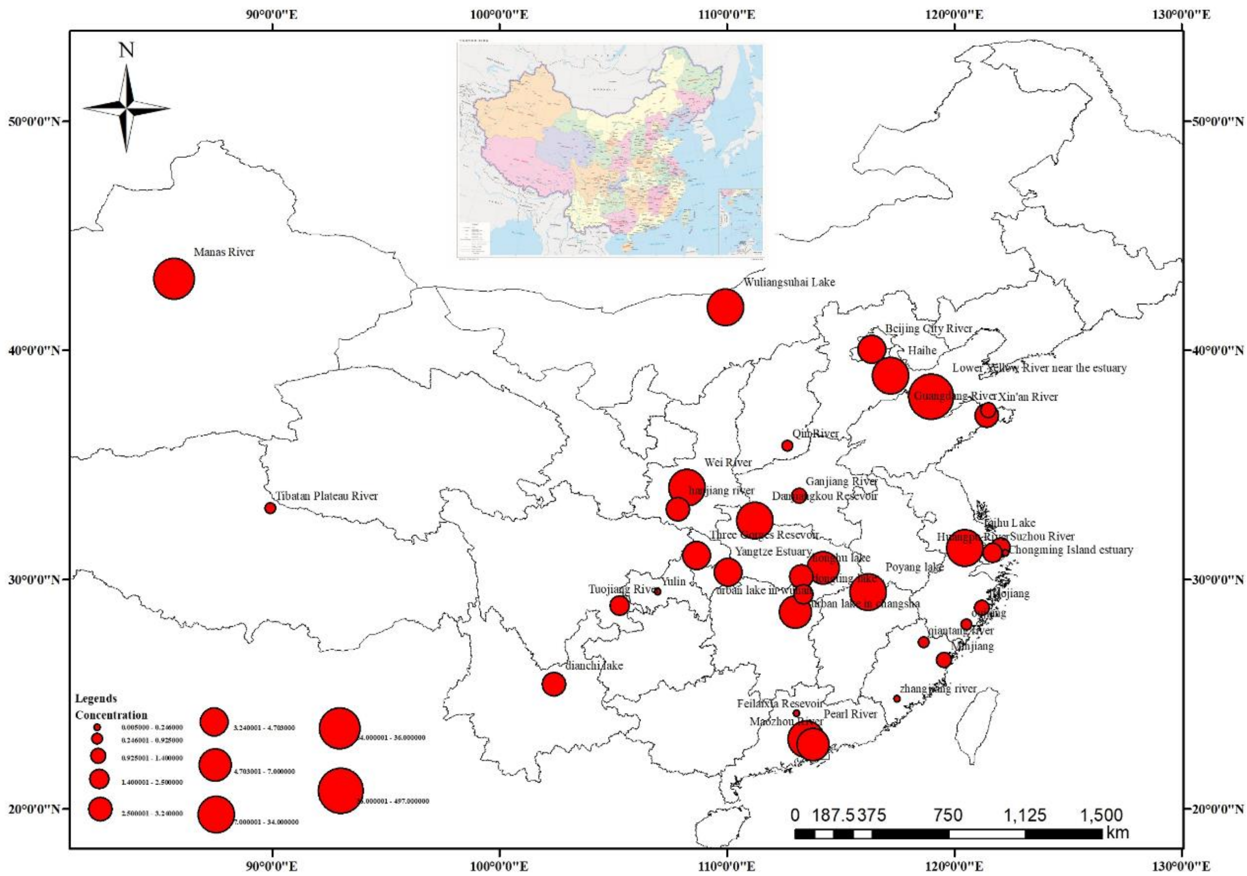

Fig. 1: Distribution and pollution degree of freshwater MPs in China

Data Mining of the Distribution of MPs in China

In this study, the spatial interpolation method was used to explore the distribution of freshwater MPs in China by the ArcGIS. The kriging method was used for spatial interpolation, which can be used to calculate the microplastic pollution concentration in an unknown area based on the existing data.

As shown in Fig. 2, we could clearly see that the whole northeast of China was facing the risk of microplastic pollution to a large extent. The microplastic concentration at the estuary of the yellow river was very high (Han *et al*., 2020) because of the large sediment content in the river and the adhesion characteristics of MPs. Moreover, microplastic pollution suggests a strong spatial correlation.

Because high-risk microplastic pollution was found in the Shandong and Jiangsu Province, we should pay more attention to their river estuaries. Besides, the results of MPs from s the manas river in the junggar basin, Xinjiang were not optimistic (21±3-49±3 items/L) (Wang *et al*., 2021; Wang *et al*., 2020). A study had also investigated Ulansuhai Lake in Inner Mongolia, and its MP concentration was 1760±710-10,120±4090 items/m^3 (Wang *et al*., 2019). Even in deep inland areas, there was still a risk of microplastic pollution, and its concentration was not lower than that of urban agglomerations. Another study in Taihu Lake indicated the concentration of MPs (100-1000 μm) on the trawl has reached $0.01*10^6$-$6.8*10^6$ items/km^2, whereas the MPs levels on the surface water were approximately 3.4-25.8 items/L (Su *et al*., 2016). Fiber is the main component, accounting for 48-84% of the microplastic pollution load. Blue MPs were prominent, contributing 50-63% among all colors. Generally, the microplastic pollution received by taihu lake is very serious, which is two orders of magnitude higher than that of Laurent Lake in the United States (Su *et al*., 2016).

MPs enter the environment *via* diverse sources and pathways (Rochman *et al*., 2019). It is undeniable that complex human activities are still the main reason for the source of MPs (Fahrenfeld *et al*., 2019; Golwala *et al*., 2021; Grbic *et al*., 2020; Kumar *et al*., 2021).

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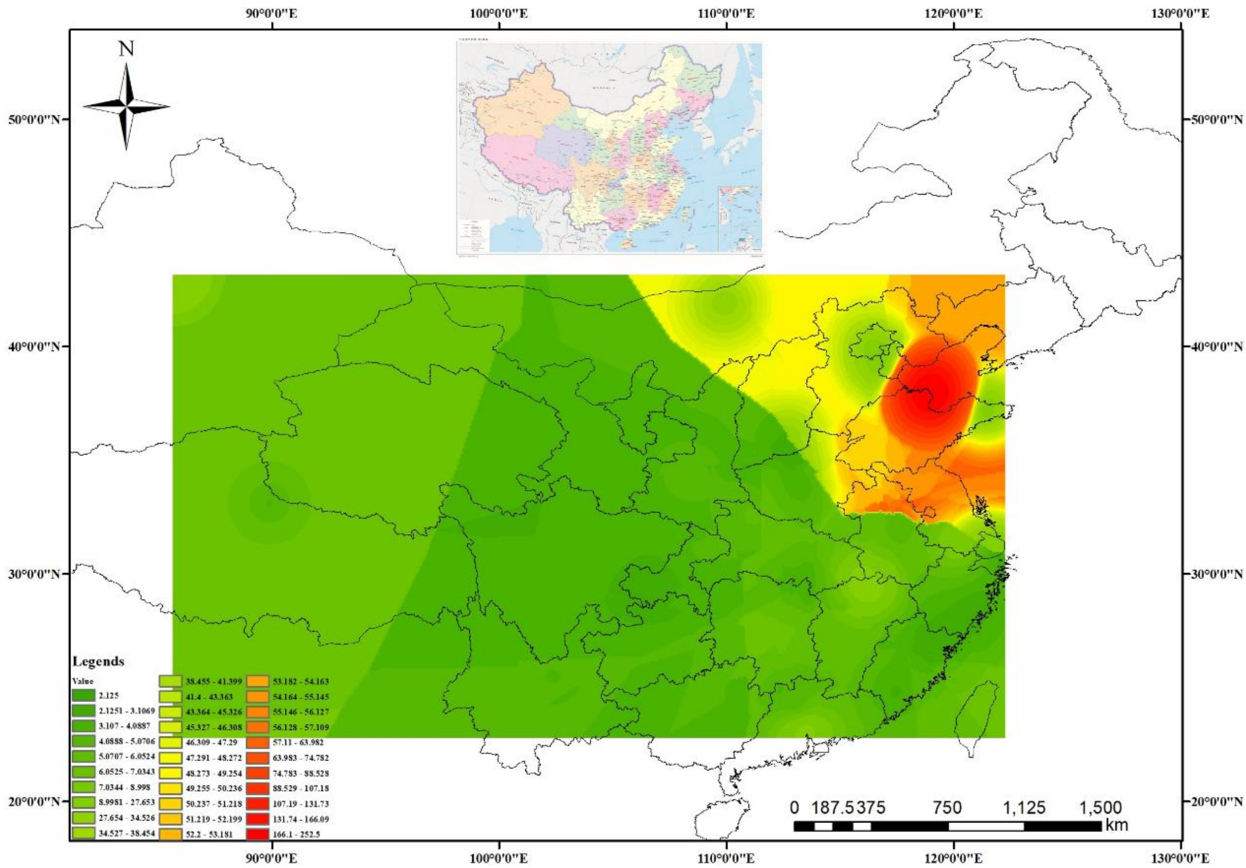

Fig. 2: Spatial analysis map of MPs in China

The differentiation of sources and paths of MPs is of great significance for controlling the occurrence of MPs in freshwater (Zhao *et al*., 2022). Wastewater is generally regarded as an important pathway for MPs entering the water body, including WWTPs effluent, industrial effluent, and overflow of sewage. Besides, anthropogenic activities, such as tourism and recreational activities, breed aquatics, and farming were other common paths mentioned in the literature, albeit atmospheric transport was also recognized to be an important pathway for MPs (Alfonso *et al*., 2021).

According to the existing freshwater reports, there was a deposition process of MPs in freshwater systems. In particular, the MPs in the yellow river are much larger than those in other areas (Han *et al*., 2020). Therefore, more attention should be paid to MPs in sediments as well as freshwater. Density plays an important role in the vertical transport of MPs (Li *et al*., 2020a). When MPs enter the aquatic environment, a part of them might descend to the sediment due to the density difference between MPs and water (Zhang *et al*., 2020). The Chongming Island estuary (Shanghai) was being contaminated by MPs, and the concentration of MPs was 10-60 items/kg (Li *et al*., 2020b), where is the estuary of the whole yangtze river. Thus, source control is crucial for reducing microplastic pollution.

China has taken many measures to restrict MPs production and single-use plastics consumption. The main sources of MPs in the Chinese freshwater system were plastic products, including daily plastic products, fishing, and agriculture products, as well as litter. The prevalent plastic products contained plastic bottles, bags, films, caps, containers, plastic pellets in pharmaceuticals, microbeads in personal care products, and plastic products (feeders, impermeable membranes, cages, floats, boats, fences, ropes, nets, oxygenators, fish packaging, and transport materials) in the fishery (Lusher *et al*., 2016). The Chinese government issued an upgraded law restricting the use of plastic products, including non-biodegradable plastic bags, single-use plastic tableware, hotel disposable plastic products, and express plastic packaging (Zhao *et al*., 2022).

Conclusion

Taken together, the pollution concentration of MPs in freshwater rivers in China should not be underestimated, and even a large number of MPs are being deposited. Now, more and more researchers begin to pay attention to the microplastic pollution in the environment of freshwater. According to the reports, the microplastic pollution along the coastline near the ocean was serious. This was a cumulative process through fluvial action. Therefore, the traceability research of MPs may be a long-term and continuous process. Plastic waste management, such as plastic reuse and recycling system, should be established to improve the recovery rate of plastic waste. Currently, due to the disunity of research methods, there are still many bottlenecks in the research of MPs. Due to the different operation methods and research objects, there are deviations in the quantification process of microplastic pollution. Therefore, the establishment of unified and reasonable standards and rules has become an important goal for MP's studies.

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Author's Contributions

Zhuo-Yuan Xie: Extracted, analyzed the data and wrote the first draft.

De-Sheng Pei: Conceived, designed and revised the paper.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

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