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REVIEW ARTICLE

Distribution Characteristics and Impact of Microplastics: A Literature Review

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ABSTRACT

Microplastic (MP) pollution in marine and lake environments has become a worldwide problem affecting aquatic ecology and human life. However, many people still ignore the severity of MP pollution. This paper expounds on seven types and two primary sources of MP, introduces the current situation of MP both in marine and lake, summarizes the adsorption of environmental pollutants, explains the harm to the human body and the existing removal technology of microplastics (MPs) by searching and summarizing previous studies. The results showed MPs is prevalent in aquatic environments and did affect biological and human health. And some effective removal technologies have been used to reduce some MPs pollution. The paper helps to better understand the pollution status of MPs and provide as reference for future research about MPs.

Contribution/Originality: This study contributes to the existing literature by providing trends, challenges, and emerging topics of MPs pollution. By reviewing a wide range of studies, we identify gaps in current research and propose new directions for future investigations. The findings not only help to consolidate existing knowledge but also provide a foundation for future research that can further advance the field.

1. Introduction

Microplastics (MPs), referring to plastic particles smaller than 5 mm, have attracted widespread attention because of their environmental persistence. The invention of plastic materials in the middle of the 19th century, coupled 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, 2018). As plastic materials are lightweight, low-cost, durable and stable chemical properties, they have been widely used in medicine, architecture, electronics, aviation, agriculture and daily life, which occupy a very common position in contemporary society (Thompson et al., 2009). Since 1950, global plastic production has increased exponentially. The extensive use of plastic products and disposal methods, mainly in the form of discarding, has brought tremendous pressure on the ecological environment. Now, global plastic consumption has exceeded 300 million tons. The concept of MP was first proposed in the study results published in Science (Thompson, 2004). It is a new environmental pollutant dispersed in soil, water, and air environmental media. The physical characteristics of MPs are considered to be dynamic. They are constantly decomposed over time to produce smaller and smaller MPs, which will eventually form less than 1 μm.

Many MPs infiltrate the environment, becoming ingested by organisms and subsequently integrated into the food chain. This process disrupts the ecological environment and induces various toxic effects on organisms and humans (Barnes et al., 2009). The ecological risk and potential harm of MP pollution have attracted global attention. The second United Nations Environment Conference in 2016 also listed plastic pollution as the second most important scientific issue in environmental and Ecological Sciences. The extent of harm inflicted by MPs is contingent upon particle size; smaller particles penetrate organs more deeply and result in more severe adverse effects (Covington et al., 2019).

1.1. Research Objectives

i. Deeply understand the types and sources of MPs.
ii. Analyze the current situation of MPs in both marine and inland water environments.
iii. Explore the adsorption of MPs in a water environment.
iv. Explain the aggregation of MPs in organisms and potential harmful effects to humans.
v. Investigate the removal technology of MPs.

2. Methodology

A literature review was the main method used in this study to look at and put together previous research papers, reports, and policy documents about MPs and how they affect distribution. A thorough examination of pertinent and available papers in databases like Google Scholar, Scopus, ScienceDirect, and associated articles in specialist fields is essential for the identification methodology. It entails sifting through all publications pertinent to the inquiry. This study tries to find a reason for the growth of MP pollution by looking at how it affects people's health by understanding MPs.

3. Results and Discussion

3.1. The types and sources of MPs

Research indicates that the environment contains seven main constituents of MPs. Polyethene (PE), polypropylene (PP), polyvinyl chloride (PVC), polyethene terephthalate (PET), polyformaldehyde (POM), nylon 6 (PA6), and polystyrene (PS) (Liu et al., 2022). The MPs categorized in the study comprised fibers, rods, ellipses, ellipsoids, spheres, quadrilaterals, triangles, amorphous shapes, and indeterminate forms. These categories were corroborated through professional evaluation of MPs across several environmental compartments. The research indicated that fibers and spheres were notably distinct in shape, whereas ellipses, ellipsoids, and rods were less well-defined (Liu et al., 2023).

MPs originated in the aquatic environment from both terrestrial and aquatic sources. The plastic trash generated from daily manufacturing and activities on land is the primary source of MPs in the aquatic environment (Horton et al., 2017). Furthermore, MPs on land will disperse into the aquatic environment due to atmospheric conditions influenced by wind, thus contributing to pollution. MPs contribute to the contamination of water supplies through aquaculture, maritime traffic, and aquatic tourism. Members of Parliament can be categorized into primary and secondary MPs based on their sources. Primary MPs comprise plastic beads incorporated into cosmetics, toothpaste, facial cleansers, and MPs generated during laundry processes. According to research, a single face scrub cleanser may contain over 300,000 MP particles (Sjollema et al., 2016). Each laundering of synthetic fibre textile garments is predicted to release approximately 1,900 MP fibers. Secondary MPs consist of diminutive fragments or strands of plastic that degrade over time due to exposure to light, weathering, hydrodynamic forces, and biological organisms. This segment of plastic garbage is introduced into the aquatic environment by water tourism, fisheries, and maritime transport. The degradation of plastic products, the disposal of plastic waste, the release of wastewater, fishing gear utilized in aquaculture, and plastic materials employed in agricultural practices may all contribute to MP contamination. A substantial quantity of plastics in the environment has become a potential cause of MP pollution.

3.2. The current situation of MPs pollution in marine and inland water

Plastic waste in coastal environments has been documented since the 1970s. However, it has garnered less public attention. It is projected that 10% of created plastic items will ultimately enter and accumulate in the marine environment. Furthermore, owing to their minimal recovery and resistance to degradation, MPs in the marine ecosystem will necessarily proliferate over time. The density of MPs in water and sediments can reach up to 100,000 items/m^3, interacting with organisms and the environment in multiple ways (Geyer et al., 2017). The ingestion of MPs by marine organisms can impact all trophic levels, leading to digestive tract obstructions, impaired nutrient absorption, compromised liver function, diminished growth rates, and weakened cognitive behaviour, thereby posing significant risks to living organisms (Hidalgo-Ruz et al., 2012).

MP pollution is equally detrimental to the ecosystem as significant plastic pollution. It is projected that in 30 years, global plastic manufacturing will attain 25 billion tons, and the volume of plastic waste in the ocean may surpass the total biomass of fish. Prior research indicated that MPs with significant prevalence can be identified in nearly every area of the worldwide marine ecosystem. Van Cauwenberghe et al. (2013) report the presence of micron-sized plastic particles in deep-sea sediments at various depths (1100 ~ 5000 m). Concurrently, Peng et al. (2017) found that the concentration of MPs in the bottom seawater of the Mariana Trench ranges from 2.06 to 13.51 pieces/L. In contrast, the surface sediments exhibit 200 to 2200 pieces/L concentrations.

Although more than 96% of the studies on MPs are concentrated in the marine ecosystem, about 80% of marine MPs are believed to come from the inland freshwater environmental system (Xu et al., 2020). The freshwater environment is closely related to the life of human society, and the investigation of MP pollution is becoming increasingly important. Lakes are relatively enclosed and serve as the primary location for accumulating land-based freshwater resources, which causes MPs to accumulate in lakes continuously. The studies showed different MPs abundance in Table 1. Sulistyowati and Nurhasanah (2021) found that the abundance of water samples in Indonesia's West Sada was between 13.33 and 113.33 items/m^3. Scherer et al. (2020) found that the MPS content of Czech Elbe water was 5.57 items/m^3. It has also been discovered that MPs detected in China's inland waters are higher than in other parts of the world. Most researchers consider the Yangtze River the most significant contributor to marine MPs in the world. The Yangtze River estuary's surface water contains up to 6500 items/m^3 and at least 2000 items/m^3 of MPs (Zhang et al., 2020). Most of the MPs are in fibre form, and the main component of the MPs is polyethene (PE). In Central China, relevant studies have found that the MPs concentration of the Hanjiang River is lower than that of the Yangtze River Estuary, which is about 2500-3000 items/m^3 (Wang et al., 2018). In the southeast coastal area of China, the average abundance of MPs in the sections of the Pearl River Estuary and Guangzhou City is about 8902 and 19860/m^3, and the main components of MPs are polyamide and cellophane (Peng et al., 2017). Two lakes in China's most developed regions, Taihu Lake and Poyang Lake, had more MPs than others (Su et al., 2016). The number of MPs in urban scenic lakes in Changsha and Wuhan was found to be relatively low, but their ability to react to changes in their environment is weak. Human or natural factors significantly influence the level of MPs in these lakes' water bodies (Zhao et al., 2015).

Table 1: The MPs abundance in other area

Number	Name	Abundance	Reference
1	Indonesia's West sada	13.33-113.33	(Sulistyowati & Nurhasanah, 2021)
2	Czech Elbe	5.57	(Scherer et al., 2020)
3	Yangtze River	2000-6500	(Zhang et al., 2020)
4	Hanjiang River	2500-3000	(Wang et al., 2018)
5	Pearl River Estuary	8902	(Peng et al., 2017)
6	Guangzhou city	19860	(Peng et al., 2017)

3.3. The adsorption of MPs

It has been found that MPs may adsorb organic pollutants (Prata et al., 2020), heavy metal ions, pathogens (Amaral-Zettler et al., 2020) and antibiotics coexisting in the environment due to their large surface area. MP particles, as carriers of these pollutants, cause long-distance transport of pollutants and transfer pollutants to the ecosystem through the food chain (Kwon et al., 2017) and increase the bioavailability of other pollutants through adsorption and bioaccumulation and enrichment effects (Guzzetti et al., 2018). However, some studies have also shown that the adsorption of MPs to other pollutants can reduce their toxicity and bioavailability (Li et al., 2018). Therefore, it is impossible to generalize whether the joint effect of MPs and other environmental pollutants is synergistic or antagonistic. This joint effect often varies according to the different pollutant types, storage environments, and particle sizes of plastics and tested organisms (Zhu et al., 2019).

3.4. Aggregation of MP in organisms

Plastic waste can be decomposed into MPs in the water environment through physical and biological degradation. Studies showed that MPs can be ingested by bivalves, zooplankton, fish, shrimp, whales, and other marine species (Rodrigues et al., 2018). Since MPs are widely dispersed in the maritime environment and extremely easily ingested by and stored in marine organisms, they are likely to impact the growth status of marine organisms. MPs are easily transferred in organisms due to their small volume. However, the method and mechanism of transfer are still unknown. Chen, Y et al. (2021) studied the growth inhibition effect of high PE, PVC and PS concentrations on Scenedesmus obliquus and found that PE had the most significant inhibition effect.

Sjollema et al. (2016) revealed that the growth of Dunaliella tertiolecta was significantly inhibited under the experimental setting concentrations of different sizes of PS. Zhang et al. (2017) studied the toxic effect of MPs on Skeletonema costatum. Algal growth inhibition experiments found that micron PVC (1 μm) has an apparent inhibitory effect on microalgae growth. In addition, the study (Zhang et al., 2017) exhibited a high concentration of micron-sized PVC (1 μm). The chlorophyll content and photosynthetic efficiency decreased under PVC treatment. It can be seen that algal cells are affected differently by different kinds, concentrations and sizes of plastic fragments.

3.5. Harmful effect of MPs on human beings

MPs in the environment could pose potential threats to human health. Some studies have simulated the harmful effect of MPs on the human body through mise experiments. After mice ingested high-concentration polyethene (PE) MPs, their intestines (colon and duodenum) showed apparent inflammation (Li et al., 2020). Polystyrene (PS) MP particles can also cause decreased intestinal mucus secretion, dysregulation of intestinal flora, intestinal barrier dysfunction and metabolic abnormalities in mice (Jin et al., 2019). Hans et al. (2015) found that MPs in the intestine can promote adsorption reactions through their surface charges, which may affect the intestine's immune system and cause local inflammation. Inflammation may be caused by the absorption of plastic particles by the intestine, forming a positive feedback mechanism.

The results of an investigation on the in vitro digestion of PS particles revealed that while the chemical composition of PS would not change, crown-like structures on its surface would result in variations in toxicity. Forte et al. (2016) experimented with PS nanoparticles on gastric adenocarcinoma (AGS) cells. They found that PS nanoparticles can affect cell viability and morphology and change inflammatory gene expression (Gasperi et al., 2018). In addition, most of the fibrous MPs inhaled by the human body may be cleared by lung mucus and cilia, and some may persist in the lungs, causing local biological reactions, especially in individuals with impaired clearance mechanisms (Gasperi et al., 2018) the immune toxicity that the immune system may produce under the invasion of MPs is mainly manifested as immunosuppression, immune activation and inflammatory reactions. In another experiment, when PE MPs were fed to mice, it was found that the increase in body mass of male mice was significantly reduced, and the proportion of neutrophils in blood in both male and female mice was significantly increased (Park et al., 2020). In addition, it was observed that the lymphocyte subsets in the spleen of mice fed with PE changed. MPs also have specific effects on the reproductive system. Park et al. (2020) discovered that mice exposed to PE MP particles significantly changed the number of live births per female mouse, the sex ratio of pups and the body mass of pups.

3.6. Removal technology of MPs

The removal technology of MPs can be divided into physical and chemical methods. Filtration is a physical procedure that includes screening, disc filtration, and membrane filtration. Nowadays, membrane technology has been widely used in water and wastewater treatment and has a good market. According to a study, the world market of membrane filtration is expected to grow rapidly and will increase from $4.71 billion in 2019 to $7.03 billion in 2024 (Kane et al., 2020). The adsorption method is another effective physical method that has attracted extensive attention in pollutant removal due to its low cost, high efficiency, and simple operation. Some researchers have proposed applying porous materials to MPs to absorb water. Due to the electrostatic interaction, hydrogen bond interaction and π - π interaction between the adsorbent and MPs, the removal efficiency is very high.

Chen et al. (2020) used magnesium/zinc-modified magnetic biochar to remove MPs from water. Sun et al. (2020) developed a firm compression sponge using chitin and graphene oxide to remove MPs, effectively adsorb various MPs at pH 6 – 8. As an alternative facility for wastewater treatment, constructed wetlands have the advantages of low cost, easy operation and maintenance. The primary mechanism is physical filtration, including plant roots, substrates, and biofilms on substrates and plants, which can reduce the gap of pore size, enhance adhesion, and change the shape and density of MPs (Chen, X. et al., 2021).

Chemical methods include coagulation sedimentation, photocatalysis and microbial degradation. Coagulation usually uses iron salt or aluminum salt that is easy to hydrolyze as a coagulant combines with small particles through the complexation of the ligand exchange process and coagulates insoluble suspended particles, bacteria and part of soluble substances in the water to form enlarged particles to make the separation process more manageable. Meanwhile, other chemical processes, such as visible light photocatalysis, a promising, environmentally friendly, low-cost and efficient process, can mineralize a variety of organic pollutants into water (H_2O) and carbon dioxide (CO_2) (Hurley et al., 2018; Lourenço et al., 2017).

4. Conclusion

This paper has reviewed many relevant studies on MPs and summarized the existing research results from several aspects. First, it explains the harm caused to the world, the primary source of plastics, and its convenience since its invention. This paper discusses the pollution status of MPs in the marine environment and other water bodies. Previous studies demonstrated that MPs could be found in all types of water bodies, but the degree of pollution varied, primarily evident in the distribution and amount of MPs. The adsorption effect on environmental pollutants has been demonstrated, showing that MPs cause harm to environmental contaminants.

Additionally, the article demonstrates from several perspectives that it causes non-negligible harm to aquatic life and people. Finally, the advantages and characteristics of the existing MP removal technology were summarized. This paper aims to find out more directions and key points for future research based on the existing research materials and provide a reference for the further treatment of MPs.

Ethics Approval and Consent to Participate

Not applicable

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Conflict of Interest

The authors reported no conflicts of interest for this work and declare that there is no potential conflict of interest with respect to the research, authorship, or publication of this article.

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