Treatment Methods and Hazards Analysis of Microplastics in the Aquatic Environment

Haoran Luo*

School of Environment, Beijing Jiaotong University, Beijing, 100044, China

*Corresponding author: 20723021@bjtu.edu.cn

Abstract. Microplastics (MPs) are tiny plastic shards with a diameter of less than 5 millimeters that are produced by many processes like the splintering of synthetic fibers. MPs pollution has become a serious problem for the ecosystem. These minute plastic fragments are already pervasive in terrestrial and aquatic habitats, endangering wildlife, ecosystems, and perhaps even human health. This paper lists and compares various MPs treatment methods, explains the potential hazards of MPs, and concludes with recommendations by comparing policies and measures in different countries. In this paper, MPs treatment methods are classified as physical, chemical and biological based on different mechanisms of action, and new treatment methods are found to have the advantage of saving resources and improving removal efficiency. The potential hazards of MPs are seen in the restriction of the activities of marine organisms, leading to drowning, asphyxiation or inflammatory reactions, and in the human population, where they enter the human system through the food chain and accumulate in various tissues, ultimately endangering health. Furthermore, by comparing the measures taken by countries to deal with plastic waste, countries should develop policies that are compatible with the disposal of MPs. This study has important implications for the development and innovation of MPs removal technology, providing a more effective and sustainable solution for countries to address MPs pollution.

Keywords: MPs, removal, health, hazards, measures.

1. Introduction

In recent years, MPs pollution has become a serious environmental issue [1]. These minuscule plastic particles have become pervasive in aquatic and terrestrial ecosystems, posing a threat to wildlife, ecosystems, and potentially human health. The marine life can consume them, including fish, birds, and marine mammals, leading to negative impacts on their health and survival. MPs can also accumulate toxic chemicals from the environment, potentially causing a transfer of these pollutants through the food chain. MPs pollution is challenging to address due to its widespread distribution and persistence in the environment. They can be transported by wind and water currents, spreading across vast distances. Additionally, their small size makes it difficult to remove them from natural systems. Addressing MPs pollution requires a multi-faceted approach involving research, policy measures, and individual actions to reduce plastic consumption and promote sustainable alternatives. By understanding the context and impact of MPs pollution, its adverse environmental impact can be reduced over time.

In recent years, traditional MPs removal methods have been widely used for the removal of MPs from natural aquatic environments and wastewater treatment plants (WWTPs). Traditional MPs removal methods include physical screening, sedimentation and adsorption. However, there are some limitations of traditional MPs removal methods. For example, the effectiveness of physical screening methods is limited by the pore size of the screen or filter paper, and the wide range of MPs sizes may not allow complete removal of all sizes of MPs particles. Secondly, sedimentation and precipitation methods require a longer time to achieve effective sedimentation, especially for fine MPs particles, which settle more slowly and take longer to achieve effective separation. Traditional methods of MPs removal often require significant energy and inputs, which can lead to high operating costs and may also result in secondary pollution of the water body. Therefore, new MPs removal technologies are needed to improve removal efficiency, reduce energy and resource consumption, and reduce the risk of secondary contamination of water bodies.

This paper lists and compares several traditional and novel MPs removal methods and briefly describes the principles of each method. It also provides ideas for other innovations in MPs removal methods in the context of national policies and measures to actively address the challenges of MPs pollution.

2. Removal Technologies of MPs

The treatment of MPs has undergone several stages of innovation and development as technology has advanced. Early research focused on discovering the presence and distribution of MPs in the natural environment through the collection of water samples as well as tissue from organisms. As the impact of MPs has been further recognized, the focus of research has shifted to the treatment and removal of MPs. Many methods have been proposed and explored, including physical, chemical and biological methods.

2.1. Physical Method

Physical methods are a common type of treatment for MPs, using the difference in physical properties between MPs and their surroundings to remove MPs particles from water or wastewater through separation and filtration. A variety of physical methods can be used individually or in combination, depending on the circumstances.

2.1.1 Traditional method

Filtration is a simple and effective method of separating MPs particles by using screens or filters of different pore sizes. As the waste water flows through a screen with the right size pore, the plastic particles are trapped on the screen and the liquid and smaller particles are discharged.

2.1.2 Magnetic separation

Magnetic separation is a technique that uses magnetic materials and an applied magnetic field to separate and extract substances [2]. With the use of an external magnetic field, the magnetic material is concentrated with the magnetic agglomerates which could adsorb MPs. By separating the magnetic agglomerates, the MPs particles are also separated together. Nanoplastics (NPs) are drawn to and adhered to bigger agglomerates using core-shell superparamagnetic iron oxide nanoparticles (SPIONs) invented by Sarcletti [2]. The water is subsequently purified of these agglomerates by applying an external magnetic field. The n-alkyl chains preferentially act on organic NPs rather than inorganic particles, and the shell molecules provide two interaction motifs for the NPs, efficiently adsorbing complementary charged MPs particles.

2.1.3 Adsorption

Innovative physical adsorption methods are currently the most widely used for the removal of MPs because of the simplicity of the process, the low cost and the high degree of industrialization. These include nano-adsorption, biochar adsorption.

Nanomaterials are used in the removal of MPs because of their high specific surface area and strong adsorption capacity. Mixing of MPs-contaminated water or wastewater with the nano-sorbent in such a way that the nanomaterials come into contact and interact with the MPs particles. According to the research by Bhore and Kamble, magnetizable organic polymetallic ion salts can effectively adsorb MPs in aquatic environments and these salts were directly created by iron oxide nanoparticles, N-containing organic bases, and POMs (heteropoly acids) in a single process (Fig. 1) [3]. The outcomes demonstrated that the Fe_3O_4(II,III)-doped nanocomposite is both ecologically benign and able to almost completely recover a variety of plastic components from solutions containing MPs (0.01-0.0025%).

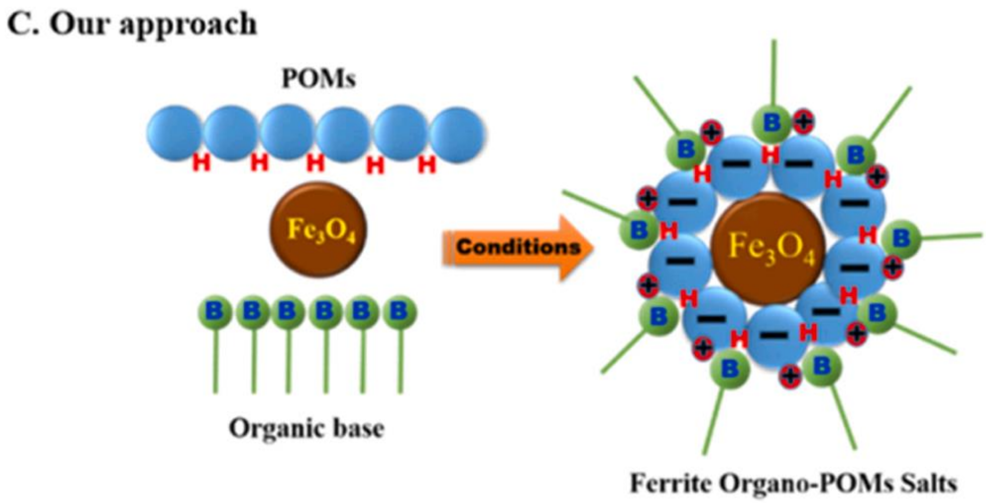

Fig. 1 Ferrite Organo-POMs Salts magnetic material for exaction of MPs. https://ars.els-cdn.com/content/image/1-s2.0-S2213343722015937-gr1.jpg

For the removal of MPs, biochar alone is not effective, but combining biochar with other modified magnetic metals to form an adsorbent can have an important impact on how MPs are affected. Wang et al. suggested a productive magnetic charcoal adsorbent that has been Mg/Zn modified [4]. Most MPs can be removed from the aquatic environment using magnetic biochar that has been treated with magnesium and zinc metals. As the catalyst, Mg and Zn could enhance the degradation of adsorbed MPs by inducing the release of adsorption sites.

2.2. Chemical Method

The chemical method is to catalyze a chemical reaction in the MPs itself or to add the substance to achieve MPs removal.

2.2.1 Electrocoagulation

The electrocoagulation method uses the electrolytic principle to remove MPs from the water by producing a coagulant on the surface of the electrode, which causes the MPs particles to coalesce into larger agglomerates, thus facilitating separation and removal.

In general, the effect of dissolved organic matter (DOM) on MPs is divided into two parts: electrocatalytic and electrocoagulation. In the electrocatalytic process, DOM promotes the production of ·OH to break down MPs, while in the electroflocculation process, DOM absorded with Fe^{2+} and Fe^{3+} ions increases the water content of the floc, thus preventing the re-entry of smaller sized plastics into the water column.

2.2.2 Photocatalysis

In photocatalysis, a catalyst is excited by light energy to induce a chemical reaction. MP removal could possibly be accomplished using photocatalysis. Through the use of photocatalysis, organic pollutants can be converted into non-toxic substances like water, carbon dioxide, and inorganic acids. It was illustrated that the synthesis of an untreated platinum or palladium-containing titanium system photocatalyst (Fig. 2) [5]. In order to achieve better degradation and increase the photocatalytic efficiency, the influence of the catalytic environment on the process should be considered. Ariza-Tarazona et al. used C, N-TiO_2 and visible light to study how pH and temperature affect the pace at which MPs degrade and result shown that low pH and low temperature both contribute to MPs breakdown [6].

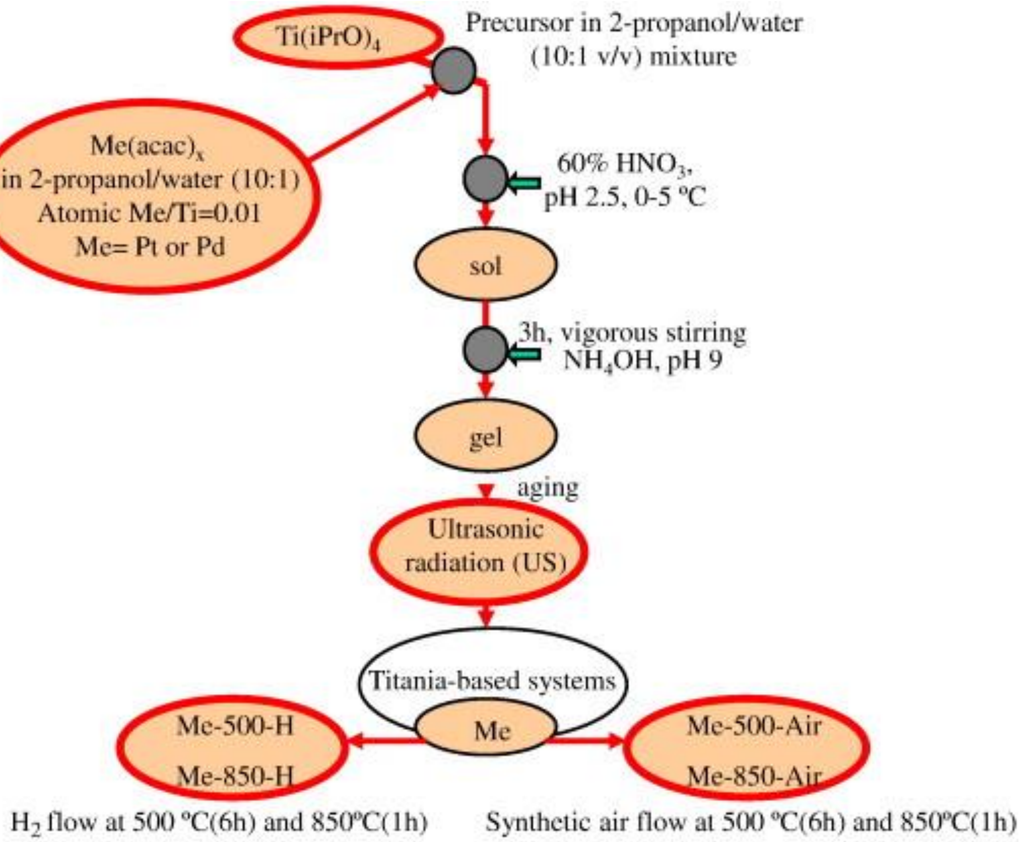

Fig. 2 Synthesis methods for photocatalytic systems. https://ars.els-cdn.com/content/image/1-s2.0-S1566736711003426-gr1.jpg

2.3. Biological Method

Biological treatment of MPs is a method that uses biological processes and organisms to degrade, transform or remove MPs. Thakur et al. discussed the part that various microbes and enzymes play in the breakdown of MPs, including *Bacillus* and *Rhodococcus*, which use various secreted enzymes to hydrolyze [7]. MPs are simultaneously broken down into smaller molecules by extracellular and intracellular enzymes, which then use these smaller molecules as a source of energy by metabolizing them into non-toxic compounds. Additionally, membrane bioreactor (MBR) is also commonly used in WWTPs to remove pollutants from wastewater, including MPs.

3. Potential Hazards

MPs, are an increasingly pervasive pollutant that poses significant risks to humans, plants, animals, and the environment due to their widespread presence.

3.1. Potential Hazards of MPs

The effects of MPs on animals are manifested in entanglement and accidental ingestion. Gall and Thompson, by collating a large body of literature on marine litter ingestion or entanglement, reported that the species most entangled in marine litter were Eubalaena glacialis and green turtles, while the most frequent regarding litter ingestion were green turtles and Eubalaena glacialis [8]. These reports cover 693 species and 92% of the organisms' contact with litter is plastic, showing that MPs are extremely harmful to marine life. It is obvious that there must be a detrimental effect on marine life, albeit the intensity of ingestion and entanglement will vary based on the type of debris and will also vary by species and individual. The effects of entanglement are manifested in restrictions on the creature's ability to move, such as drowning, suffocation, and inability to effectively avoid predators.

3.2. Human Health

As previously indicated, there are risks associated with MPs for animals, and these risks are increased by the food chain if aquatic organisms consume them. Not only do humans cause plastic pollution, but also the aggregate of MPs contamination.

With the constant consumption of food containing MPs, the human body becomes enriched with these contaminants, which is harmful to the body. The digestive system and lungs of chickens are the primary entry points for MPs and NPs, which then accumulate in a variety of tissues. With the processing of food packaging, this plastic debris in livestock products steadily builds up and finally poses a direct threat to human health. Studies have demonstrated that MPs can result in increased protein and gene expression of inflammatory markers [9]. Cells exposed to MPs were found to exhibit reduced activity by extracting MPs of various sizes and sizes separated from various water depths, which offered a fresh viewpoint on how plastics can impair the human body.

4. Measures

Countries are pursuing a variety of steps to minimize the creation of plastic waste in response to the negative impacts that MPs have on the environment, animals, and people. By the end of 2020, the Chinese government implemented a new regulation known as the 'Plastic Restriction Order', aimed at curbing the usage and production of plastic, banning the use of single-plastic products in catering industry, supported by fines and subsidies.

However, Thailand has encountered challenges in dealing with the disposal of plastic waste. After China made measures to restrict its own waste imports, although the Thai government established a corresponding system, it neglected to control and monitor illegal smuggling activities, leading to a surge in plastic waste imports, with similar situations occurring in Southeast Asian countries such as Vietnam and Malaysia [10]. Therefore, it is important to ensure that appropriate international mechanisms for the recycling and disposal of plastic waste.

By including MPs in the monitoring criteria, it facilitates the early detection and assessment of potential risks and the adoption of appropriate protective measures to safeguard public health. According to Gago et al.'s study of the Marine Strategy Framework Directive, new methods for the quick and affordable identification of MPs must be created and subsequently validated, much as they are now for characterizing plankton and particulate matter [11].

5. Conclusion

The handling of MPs is relevant to all aspects of the ecology and human society. This paper classifies different MPs treatment methods according to their mechanism of action and compares the advantages and disadvantages. In comparison to conventional treatment methods, new technologies have been developed to improve removal efficiency through innovative mechanisms and designs, ensuring that a higher proportion of MPs are effectively removed. In addition, the potential hazards of MPs for organisms and humans need to be taken into account, as MPs can adsorb and enrich toxic substances, such as heavy metals and organic pollutants. When these MPs containing toxic substances are ingested by organisms, they can lead to toxicity and physiological dysfunction. MPs enter the human body through food, drinking water and air. Although the long-term effects of MPs on human health are not known, some studies suggest that ingestion of MPs may be associated with potential health problems, such as inflammatory reactions. This paper provides observations on national approaches and policies to address MPs, proposes the inclusion of MPs in routine testing indicators to help assess potential risks associated with human health, understand people's exposure to MPs so that associations with health problems can be assessed and appropriate measures can be taken to reduce potential health risks.

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