Research on Ecological Effects of Microplastics and Removal Methods

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Abstract. In recent years, with the continuous accumulation of microplastics (MPs), the environmental pollution caused by MPs has become increasingly serious. In this paper, whether the accumulation of MPs will cause serious damage to the ecological environment and organisms and if harm is caused, how to eliminate it are analyzed. The results show that MPs are mainly produced by human activities, which have caused pollution to the water environment, soil environment and atmospheric environment. MPs destroying the water cycle, enriching heavy metals in the soil and aggravating the greenhouse effect indirectly threaten the organisms living in the environment. Due to the large amount of MPs enrichment, the survival rate of soil animals and aquatic animals is decreasing year by year, their growth and development are seriously inhibited, and the living conditions are becoming difficult. Because of the blockage of MPs, the ability of plant roots to absorb water is greatly reducing, the activity of various enzymes in the plant body is decreasing, and the efficiency of photosynthesis is affected. As the highest trophic level, humans are naturally not immune to the harm of MPs. The higher the trophic level, the more enriched the content of MPs, which poses a great threat to health. In the future, the elimination of MPs will become a focus of attention. The existing physical treatment method, chemical treatment method and biological treatment method should be improved and reasonably combined to achieve the optimal treatment effect, hoping to reduce the harm of MPs as much as possible.

Keywords: MPs; ecological environment; organisms; removal methods.

1. Introduction

MPs refer to plastic particles with a diameter of less than 5 mm, which is formed because plastic products in the environment are gradually broken and decomposed into small particles of MPs after a long time of weathering, degradation, and microbial mediation. In recent years, with the continuous accumulation of MPs in water, soil and atmospheric environment, the environmental problems caused by MPs have gradually become prominent, causing people's attention and hot discussion. Therefore, the correct understanding of the harm of MPs to the ecological environment and organisms and how to eliminate MPs in the environment has become the primary goal of research.

At present, the research on MPs in the water environment is relatively mature. Whether it is studying the source of MPs in the water environment, the harm to the environment and organisms, or the removal methods of MPs in the water, the research methods are extremely rich. In contrast, the research on MPs in the soil environment is not so comprehensive, which may be due to the complex biological structure of the soil and incomplete detection methods. Therefore, the research on soil MPs is just in its infancy, and there is a lot of room for research in the future. Researches on MPs in the atmosphere are even more scarce. Most of the existing papers focus on the migration and transformation, formation mechanism and composition of MPs in the atmosphere. However, the harm to the atmospheric environment and the transformation of MPs in the atmosphere-ocean system are rarely discussed. Based on the blank of previous studies, the harm of MPs to soil and atmospheric environment was explained in detail in this paper.

The main purpose of this paper is to analyze the impact of MPs on the ecosystem and the removal methods. Firstly, this paper explores the source, migration and transformation process of MPs in the ecological environment, and then expounds the harm of MPs to water, soil and atmospheric environment. Then, based on the fact that the organisms living in this ecological environment are also inevitably poisoned by MPs, this paper summarizes the impact of MPs on animals, plants and even

humans. Finally, this paper lists the application, advantages and disadvantages of three kinds of treatment methods, namely physical method, chemical method and biological method.

2. Impact on Ecological Environment

In today's global ecological environment, MPs have become ubiquitous. There is an inextricable relationship between human activities and MPs pollution. As is shown in Fig. 1, MPs accumulate in large quantities in rivers, lakes, oceans and even polar ice and snow regions, causing serious water pollution [1, 2]. MPs pollution in soil environment is mainly caused by sewage irrigation, atmospheric subsidence, agricultural facilities, construction site dust screen etc. Plastic waste stacking, landfill and combustion processes cause serious pollution to the atmospheric environment [1].

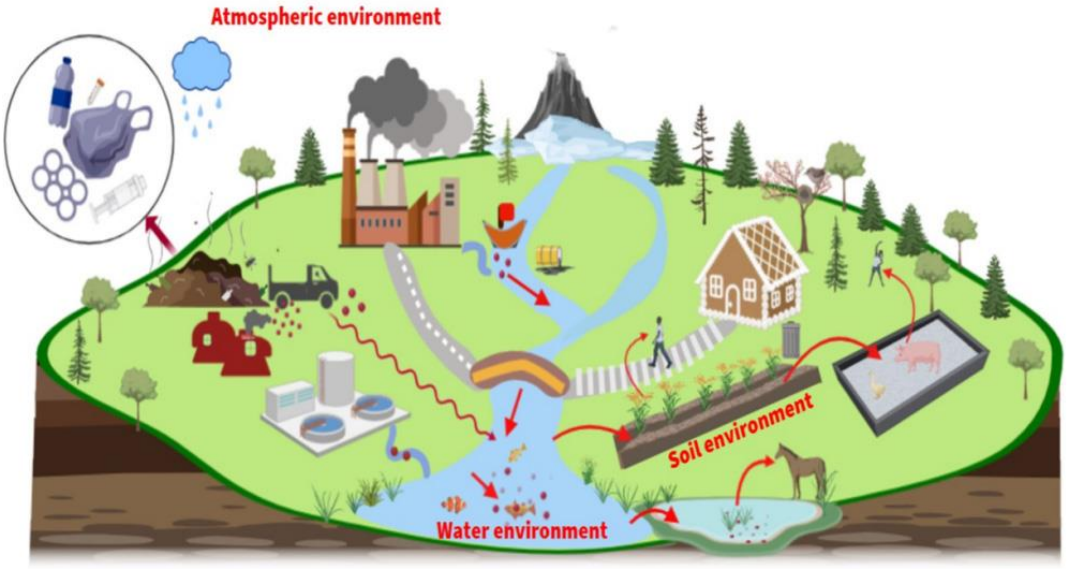

Fig 1. Migration and transformation of MPs in ecological environment.
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2.1. Impact on Water Environment

In the processing and production of MPs, it is often necessary to add many additives, such as surfactants, antioxidants and brominated flame retardants [3]. When MPs enter the water environment and are gradually degraded, these additives will be separated from the MPs and release a large number of harmful substances, seriously polluting the water environment. At the same time, MPs themselves have the characteristics of small volume, large specific surface area, difficult degradation, and strong adsorption capacity, which make them suitable carriers for various pollutants [4]. When MPs enrich a large number of other pollutants in the water environment, it is easy to produce new compound pollutants and aggravate the degree of pollution. MPs have a significant adsorption effect on organic pollutants such as polychlorinated biphenyls and organic pesticides. In addition, the adsorption of heavy metals by MPs cannot be ignored. Ye et al. found that polystyrene (PS) was more likely to adsorb heavy metals than other MPs, and lead (Pb) was more likely to be adsorbed by MPs than other heavy metals [5]. MPs also have the ability to absorb toxic substances in the water environment, and this toxicity is hard to degrade. As a result, as MPs slowly accumulate, the toxic components of the water become larger and larger. When a certain number of MPs accumulate in a water body, the water cycle is disturbed and function abnormally. Due to a large amount of MPs waste floating on the surface of the water body, the exchange of water and oxygen is inhibited, so that the water cycle is adversely affected.

2.2. Impact on Soil Environment

MPs in soil degrade very slowly due to their long-term lack of ultraviolet radiation and severe physical wear. These MPs persist for a long time and accumulate continuously to form MPs pollution in the soil environment. Due to its super-strong adsorption capacity, MPs can combine pollutants in the soil environment together, and it is likely to interact with other pollutants to form new complex pollutants, which seriously affects soil quality, reduces soil function and creates security risks for food and other crops.

The accumulation of MPs is also able to change the physical and chemical properties of soil. The effect of MPs on soil physical and chemical properties is influenced by many factors such as MPs content, MPs structure and properties (type, particle size, shape, etc.) and soil type [6]. MPs often migrate into soil aggregates in the form of different physical particles, affecting soil aggregates to a certain extent, and further causing changes in soil bulk density, bulk density, permeability, water conductivity, porosity, electrical conductivity, water holding capacity, cation exchange capacity and other physical and chemical properties. These changes usually accelerate the evaporation of water in the soil, make the soil cracks larger, and increase the degree of dryness. Changes even lead to the migration of pollutants along the soil cracks to the deep layer, and aggravate the persecution of MPs on the soil environment. Soil water circulation can also be disrupted, causing disruptions in the transport of water and nutrients in the soil.

MPs can also affect the form of heavy metals in soil, which in turn affects the bioavailability of heavy metals in contaminated soil. Jiale Xu et al. found that adding plastic film material polyethylene (PE) and tire wear particles (TWPs) to soil would significantly affect the bioavailability of lead and cadmium in soil contaminated by heavy metals, and the effects on lead were more significant [7]. This may be related to the competitive adsorption of heavy metals by MPs and soil and the composition of MPs themselves.

2.3. Impact on Atmospheric Environment

Atmospheric MPs are mainly produced indoors and transported and transformed by atmospheric circulation. MPs in the atmosphere can reduce the atmospheric visibility and even affect the solar radiation balance by absorbing or scattering light. It also reflects solar radiation and has a cooling effect on the climate. Local atmospheric warming and cooling processes in urban areas with heavy air pollution have been affected by atmospheric MPs [8]. As MPs accumulate in the atmosphere, the effects on Earth climate will become more and more intense. Atmospheric MPs affect both chemical and optical properties of clouds, and have the effect of altering atmospheric humidity and precipitation. When MPs exist stably, they often adsorb other components in the atmosphere, forming complex pollutants to further harm the atmospheric environment. Atmospheric MPs may also have a certain impact on global scale environmental processes such as biogeochemical cycles and global climate change. For example, MPs can affect carbon dioxide content in the atmospheric environment through ways such as weakening plant photosynthesis [8].

3. Effects on Organisms

MPs are not only pollutants themselves, they can also accumulate along the food chain and carry other harmful substances into living organisms. Organisms absorb MPs into their bodies through epidermal absorption and penetration, respiration, ingestion of the digestive system and other ways, resulting in a series of adverse reactions.

3.1. Effects on Animals

MPs have significant hazards to zooplankton in water bodies. The color and size of MPs in the water are very close to the food of zooplankton, resulting in a large number of zooplankton ingestion of MPs to produce a variety of injuries. For example, MPs can have an impact on individual plankton, because swallowing a large amount of MPs is difficult to digest, so that zooplankton have a strong

sense of satiety, affecting their normal food intake. MPs can also be toxic to the health of zooplankton when swallowed, and in environments with high concentrations of MPs, zooplankton may even face the risk of extinction. In general, MPs are more damaging to zooplankton than other aquatic animals.

As an important part of the water ecosystem, fish's healthy survival maintains the stability of the whole water environment. MPs can hinder the behavior of fish. MPs with small particle size penetrate the fish skin into the muscle tissue, damage the muscle tissue, and make the fish produce behavioral inertia, which hinders their activity speed, and greatly reduces their activity. MPs can also reduce the survival rate of fish, affect fish's growth and gene expression, and increase the chance of disease and other adverse effects. It is seen that the impact of MPs on fish is not to be underestimated.

The reproductive toxicity of MPs to soil animals such as earthworms is also very significant, mainly in inhibiting the growth rate, reducing the reproductive rate and survival rate, and then reducing the biomass of soil animals. The toxic effects of MPs on mammals are mainly manifested in neurotoxicity, reproductive toxicity, inflammatory reaction and lipid peroxidation [9].

3.2. Effects on Plants

MPs in soil migrate and accumulate in plants for a long time. MPs of different concentrations and types delay plant seed germination, inhibit plant development, and induce ecotoxicity and genotoxicity in different degree. MPs inhibit seed germination and water absorption, and restrict plant growth by blocking seed sac holes, root water absorption holes and other pore structures in plant bodies. MPs inhibit the activity of catalase (CAT) and other enzymes in plants, affect plant metabolism, induce oxidative stress reaction, and reduce the efficiency of plant photosynthesis. In addition, MPs can indirectly affect plants by changing the composition and structure of animals and microorganisms in soil. MPs also have a huge impact on aquatic plants. Different concentrations of MPs in the environment accelerate the form of different phytoplankton community structure. MPs weaken the absorption and utilization of nutrients by aquatic plants and break the balance mechanism of population regulation. MPs can also disrupt the growth cycle of algae, greatly reducing photosynthetic activity. Ting Zheng et al. found that three kinds of polystyrene microspheres (PS, PSC, PSN) with different surface modifications (primitive, carboxylated and aminated) inhibited the germination rate of rice seeds and seedling root quality to different degrees, and the inhibition degree was PSN>PSC>PS. Moreover, the effect of MPs on the growth and antioxidant system of rice sprouts was much lower than that on roots [10]. Yang et al. found that polyethylene microplastics (PE-MPs) promoted the root length and carbon content of pepper plants, but reduced plant height and yield [11]. It can be seen that MPs have certain hazards in agricultural production, and the content of MPs in soil, water and other environments should be reduced in production activities.

3.3. Effects on Humans

MPs have been detected in some animals at lower trophic levels, and they accumulate along the food chain as trophic levels rise. The higher the trophic level, the higher the content of MPs in the body of organisms, and it is difficult for humans, the highest trophic level, to ensure that they are not harmed by MPs. Although when humans ingest food, many specific parts of food rich in MPs can be screened and removed to prevent ingestion. However, parts of the MPs in the low trophic level enrichment process have penetrated into biological tissue cells. These MPs are very likely to enter human bodies along the food chain, which can be absorbed into the stomach and intestines to change intestinal metabolism and microbial composition, endangering human health.

In addition, MPs in the atmosphere also have a strong negative effect on human health. The human body is exposed to the atmosphere for a long time every day, and MPs can be easily inhaled into the body. Atmospheric MPs have a carrying effect on many human allergens and pathogenic agents, helping pathogenic bacteria and other microorganisms enter the human body smoothly, which may lead to inflammation, hypersensitivity, respiratory infection and other serious diseases.

4. Removal Methods

MPs have a negative impact on ecosystems and organisms, so how to efficiently remove MPs is a problem that must be solved. At present, the commonly used removal methods of MPs are divided into three categories: physical method, chemical method and biological method. Each of the three methods has advantages and disadvantages, and a combination of them may achieve the best results.

4.1. Physical Method

Physical treatment has become the most widely used MPs removal method because of its low cost, simple process and high industrialization degree. Physical method is the use of separation, filtration, coagulation-ultrafiltration, flocculation sedimentation, strong extraction, grid interception, sand filter membrane filtration, nano adsorption, activated carbon adsorption and other physical methods for the initial removal of MPs process. Although the physical method is the most widely used process for the removal of MPs in sewage treatment plants, the physical method can only filter out MPs with large particle size or easy to be initially separated, and cannot completely decompose and remove MPs. Therefore, to achieve the goal of complete removal of MPs, physical methods still need to be used in conjunction with other chemical and biological methods [12].

4.2. Chemical Method

The working principle of the chemical method is to catalyze the chemical change of the MPs themselves, or to add a certain substance to undergo a chemical reaction process to remove the MPs [12]. Chemical methods include ozone degradation, electrocoagulation, ultraviolet oxidation, photocatalysis, persulfate oxidation, Fenton oxidation, advanced oxidation and other treatment methods. Chemical methods are usually able to completely break down MPs, and the rate of decomposition is also faster than biological methods. However, a certain number of chemical reagents, such as coagulants and catalysts, will be put into the process of chemical treatment of MPs, which is easy to cause secondary pollution and increase the cost of subsequent treatment [12].

4.3. Biological Method

Biological method mainly refers to the hydrolysis and digestion of MPs by fungi, bacteria and other microorganisms and extracellular enzymes [13]. Microbial degradation of MPs mainly includes the following five stages: microbial adhesion on the surface of MPs, microbial film formation, biological corrosion, biological fragmentation and mineralization [13]. Biological treatment methods basically include activated sludge, membrane separation, membrane bioreactor and biodegradation. Biological method can achieve effective degradation and mineralization of MPs in water, but it takes a long time and has low treatment efficiency. As an environmentally friendly degradation method of MPs, the biological treatment of MPs requires relatively strict reaction conditions [13]. Microbial degradation technology combined with chemical pretreatment technology is developed, which makes microbial degradation of MPs low cost, economical and feasible.

5. Conclusion

MPs penetrate into every corner of the environment, which is detrimental to the ecological environment and biological health. MPs exist in the environment for a long time, because they are difficult to degrade, causing irreversible damage to water, soil and atmospheric environment. A large number of MPs in the water body accumulate and float on the surface of the water, so the water cycle is disturbed and cannot operate normally. MPs in soil have the ability to adsorb heavy metal ions, which intensifies the heavy metal pollution of soil environment. MPs in the atmosphere have a huge impact on global climate change and catalyze the greenhouse effect. MPs pollution in the environment can also indirectly harm the survival and reproduction of organisms. Animals ingested MPs, resulting in behavioral inertia, toxic reproductive systems, and developmental delays. Plants absorb a large number of MPs, leading to the blocked porous structure, and the ability to absorb water and nutrients

is gradually reducing. Humans eat animals and plants that contain a lot of MPs in their bodies, and over time, human health will be threatened. The harm of MPs to the ecological environment and organisms cannot be ignored, and how to efficiently and conveniently eliminate MPs is the top priority. Today, physical, chemical and biological methods are the main MPs elimination methods. In the future, with the development of science and technology, these three methods will certainly have innovative progress, and can be more skillfully combined and used to minimize the harm of MPs.

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