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Research Progress of Microplastics Pollution in Environment

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Abstract Microplastics pollution has become one of the focuses of global environmental science research. Microplastics include micro plastic particles and nano-plastic particles, which come from the decomposition of plastic products, the release of microfibers and the industrial process of plastic particles. The distribution of microplastics in water, soil and atmosphere is summarized, and the widespread existence of microplastics in different environmental media is emphasized. This paper also summarizes the potential impact of microplastics on ecosystems and organisms, and pays attention to the transmission and accumulation of microplastics in the food chain, as well as its potential threat to human health. Finally, the paper discusses the methods and technologies of microplastics treatment and monitoring at present, and puts forward the direction of further research on microplastics pollution in order to formulate more effective management and mitigation strategies.

Key words Microplastics, Environment, Pollution

1 Introduction and source of microplastics

Microplastics pollution refers to tiny plastic particles in the environment, which mainly come from the decomposition, weathering, washing and wear of plastic products, as well as the decomposition of plastic wastes. Generally, microplastics refer to plastic particles with a diameter less than 5 mm, including nano-scale and micron-scale particles.

According to the formation mode, microplastics can be divided into primary microplastics and secondary microplastics. Primary microplastics are tiny particles or powders produced in the production process, which mainly come from domestic sewage and industrial wastewater. Secondary microplastics refer to plastic particles or fragments that are gradually broken and formed by large plastic products under the influence of external forces such as solar radiation, ocean currents and wind power in nature[1].

The global plastic production and use are increasing continuously, and it is estimated that 7.3×10^8 t of plastic waste will be produced by the middle of this century. About 80% of the plastic waste will not be recycled, but will directly enter the natural environment or landfill. In the long-term landfill process, plastic waste is affected by physical, chemical and biological factors, and will eventually be decomposed into microplastics[2].

When the global COVID-19 epidemic broke out in 2020, World Health Organization (WHO) estimated that the world needs 89 million disposable masks per month for prevention and control work. Due to epidemic factors, the use of disposable plastic products has increased, such as bags, lunch boxes and plastic water bottles. Improper handling of these products brings great pressure to the environment. Plastic waste will gradually decompose into tiny plastic particles through various processes, which will spread into the environment and form new plastic pollution, which is called "microplastics".

According to the sources, microplastics can be divided into primary microplastics and secondary microplastics. Primary microplastics refer to intentionally produced plastic particles, such as microbeads in cosmetics, plastic particles and resin particles of industrial raw materials, *etc.* Secondary microplastics refer to plastic particles released into the environment during mechanical decomposition, photolysis, thermal decomposition and biodegradation, such as microplastics produced by aging and decomposition of plastic bags and wear of rubber tires[3].

Recent studies have found that microplastics exist in breast milk, and microplastics in food are not only from environmental pollution, agricultural production and food processing, but also from the wear and tear of food packaging materials and packaging process. It is estimated that the number of microplastic particles consumed by human beings through food may reach 39 000 to 52 000 every year, which poses a serious threat to people's health. At the same time, it is found that the surface of microplastics is easy to adsorb various toxic chemicals, such as persistent organic pollutants and heavy metals, and is easy to enrich various microorganisms. These findings emphasize the importance of continuous attention to microplastics in food safety[4].

2 Distribution of microplastics in the environment

2.1 Atmosphere Atmosphere plays an important role in the migration of microplastics, and atmospheric dry and wet deposition is one of the main ways for microplastics to enter a certain area. At present, there are few and immature studies on the temporal distribution of atmospheric microplastics, and no universal law has been found. Generally, the concentration of microplastics deposition in the atmosphere is relatively high during the period of heavy precipitation. Although the amount of microplastics in the atmosphere is less than that in fresh water and ocean, it is one of the

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important sources of microplastics in these environments, and it is of great significance to evaluate the amount of microplastics in the atmosphere[5].

In most studies, the size distribution of microplastics in the atmosphere shows that the number of microplastics particles with size <0.5 mm is the largest, accounting for more than 50%, and even some studies show that it exceeds 90%. In some studies, although the proportion of microplastics <0.5 mm is relatively low, it is still more than 20%. The proportion of microplastics in the size range of 0.5-1.0 mm changes relatively little in different study areas, and is basically stable at about 20%. By contrast, the proportion of microplastics >1 mm in size fluctuates greatly, which may be as high as 50% in individual studies[6]. Generally, the proportion of microplastics with size >1 mm is relatively small. These findings highlight the size distribution characteristics of microplastics in the atmosphere, and provide important clues for further understanding its influence and management. It should be noted that these data may vary according to different research methods and geographical areas.

2.2 Water bodies The increasing marine litter poses an increasing threat to the coastal environment and marine ecosystem. The results show that the proportion of plastic products is the most significant among all kinds of marine litter. According to statistics, about 12 million t of plastic products flow into the ocean every year and spread to various parts of the world along with the ocean. It is also found that microplastics in marine environment are affected by wind, season, climate, and ocean current, and can migrate on a global scale, from continental coast to deep sea, from hot equatorial region to cold north and south poles, from shallow seawater surface to deep sea trench of ocean. Microplastics have been widely distributed in every corner of the world's waters, almost everywhere. This highlights the urgent need for global marine plastic pollution management and protection measures[7].

A large amount of plastic waste was found in the relevant waters of the North Pacific Ocean, and the estimated plastic density was as high as 330 000/km^2. This figure is equivalent to six times the density of plankton, which makes people begin to discover the severity of marine plastic pollution. In 2004, the concept of "microplastics" was introduced for the first time to describe small and medium-sized plastic fragments (<5 mm). Since 2011, UNEP has paid attention to microplastics, and listed marine microplastics as an emerging environmental issue in its 2014 report. These research results make people pay more attention to the urgency of plastic pollution in marine environment[8].

According to the distribution of marine microplastics in the world, coastal areas are seriously polluted areas, especially in economically developed areas such as ports, river estuaries and deltas. Microplastics have many types of adsorption points and strong hydrophobicity, and can adsorb organic matter (dioxin, *etc.*) and heavy metal pollutants (chromium, lead, cadmium, *etc.*), and can also enrich microorganisms, which makes the pollution problem more complicated. The collection methods of seawater samples mainly include trawl method, pump method and water container method. Different sampling methods can be used to make us collect seawater samples with different depths and volumes, and fully grasp the distribution of microplastics in the ocean[9].

2.3 Soil Sanitary landfill becomes the main accumulation place of microplastics. Plastic mulch film will release microplastics into soil after mechanical wear and photothermal aging, and becomes one of the main sources of microplastics in farmland soil. The results show that the abundance of microplastics increases with the increase of plastic film input and plastic film mulching time. These findings emphasize the importance of plastic pollution in agricultural production.

Studies have shown that microplastics accumulated in soil will destroy the integrity of soil structure, lead to changes in soil physical and chemical properties, and thus affect the health of the whole soil ecosystem. At the same time, microplastics will directly or indirectly affect the growth and development of plants, and enter the human body through the food chain, which will adversely affect the healthy development of human beings. These findings emphasize the importance of continuous attention to microplastics in soil and crops[10].

In recent years, the existence of microplastics in soil has attracted wide attention. According to the study, the content of microplastics found on land may be 4-23 times that of the ocean, and the annual discharge of microplastics to farmland in Western Europe and North America reaches 110 000 and 730 000 t. Soil, especially farmland soil, may be a more important collection place of microplastics than water environment. Related research reveals the pollution of microplastics in abandoned salt fields on the east coast of China. Since then, China has launched a series of investigations on soil microplastics pollution. In coastal areas such as Qiantang River Estuary, Bohai Bay and Southern Yellow Sea, researchers found high concentrations of microplastics, with the highest concentration reaching 14 712.5 per kilogram of soil. In addition, researchers have detected the existence of microplastics in farmland in Heilongjiang, Shihezi, Jianghan Plain, Yangtze River Delta, Haihe River, Jizhong Plain and Shaanxi. What is more striking is that microplastics have been found even in the soil of Tibet, which further shows the universality of microplastics pollution in the soil environment of China. This phenomenon highlights the urgent concern about soil microplastics pollution, and more targeted measures are needed to monitor, prevent and slow down the progress of this problem[11].

Although degradable plastics are a solution to reduce the pollution of current non-degradable plastics, their degradation rate under natural and controlled conditions is still slow. Therefore, the detection of microplastics such as degradable plastics is of great significance for assessing the potential ecological and health risks brought by soil microplastics. These research efforts are helpful to formulating more effective plastic pollution management strategies, thus protecting the ecological environment and human health[12].

3 Hazards of microplastics

3.1 Effects on aquatic organisms A large number of aquatic organisms will eat microplastics by mistake, which will lead to the accumulation of microplastics in the food chain, and finally have adverse effects on the stability and health of the whole ecosystem. This trend not only threatens the balance of marine and freshwater ecosystems, but also may have a long-term impact on fishery resources and biodiversity[13].

3.2 Water pollution Microplastics can enter the water body and deposit at the bottom or float on the water surface, which has a negative impact on the ecological balance and quality of the water body. This kind of pollution not only affects the living conditions of aquatic animals and plants, but also damages the water landscape and ecological landscape, and affects human recreational activities and eco-tourism[14].

3.3 Soil contamination Plastic particles may enter the soil through fertilizer or sewage, which affects the quality of soil and has a negative impact on the growth of plants and soil ecosystem. This kind of soil pollution may weaken soil fertility, lead to the decline of crop yield, and may also have a long-term impact on natural vegetation and soil microorganisms in the ecosystem[15].

3.4 Potential impacts on human health Microplastics may enter human body through food chain, which has potential impact on human health. Although there is no clear evidence to prove that microplastics are directly harmful to human body, researchers are still trying to identify their potential health risks, especially the potential threats to human health caused by long-term exposure. Therefore, the research and monitoring of microplastics is of great significance for protecting ecosystems and human health[16].

4 Testing method of microplastics

4.1 Visual method Visual method relies on naked eyes or with the help of microscope to identify the appearance and structural characteristics of microplastics. Microplastic particles with a particle size larger than 1 mm can only be identified by naked eyes, and particles with brighter colors are usually easier to identify. For those smaller microplastics, they need to be identified by microscope[17].

4.2 Spectral analysis Infrared spectroscopy is a non-invasive detection technology, which can analyze samples quickly and non-invasively, so it is widely used. By contrast, Raman spectroscopy has higher resolution (up to 1 micron), wider wavelength range and good sensitivity to nonpolar functional groups. However, the Raman spectrum is easily affected by fluorescence noise and the measurement time is unfriendly, which limits its application in detection[18].

4.3 Analytical method Thermal analysis uses the physical and chemical properties of polymers to observe and identify, and then identifies the composition and types of microplastics. It mainly includes pyrolysis gas chromatography/tandem-mass spectrometry, thermal extraction-thermal desorption gas chromatography/tandem-mass spectrometry and thermogravimetric analysis differential scanning calorimetry. The application of these technologies can help us to deeply understand the properties and sources of microplastics and provide important scientific evidence and support for pollution control[19].

5 Conclusions and prospects

5.1 Conclusions In the field of microplastics research, some important conclusions have been drawn, and some prospects have also been put forward. Studies have shown that microplastics pose a potential threat to ecosystem and human health, so effective measures should be taken to mitigate its impact. Some important conclusions include the following:

Microplastics have been widely distributed in water, soil and food chain all over the world, which has a negative impact on aquatic organisms, soil ecosystems and human health. Microplastics easily adsorb toxic chemicals, which makes them more toxic and poses potential hazards to ecosystems and human health. The long-term accumulation of microplastics in the environment may lead to sustainable damage to ecosystems, aggravate the reduction of biodiversity and the destruction of ecological balance[20].

5.2 Prospects Future research needs to continue to explore the source, migration, transformation and impact mechanism of microplastics on ecosystem and human health. At the same time, scientists are also looking for effective ways to solve the problem of microplastics pollution, including but not limited to: formulating stricter environmental protection laws and policies, limiting the production and use of plastic products, promoting plastic recycling, and reducing the emission of plastic waste; developing new degradable plastic substitutes to reduce the impact of plastic products on the environment; strengthening public education and awareness raising, encouraging environmentally friendly lifestyles, and reducing the use of disposable plastic products; developing more advanced monitoring and detection technology of microplastics, and improving the ability to accurately evaluate the pollution degree of microplastics[21].

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(From page 18)

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