Research of New Pollutant Microplastics in Soil

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Abstract. Microplastic pollution is one of the key new pollutants to be controlled in ecological environment protection. This article describes in detail the abundance and distribution of microplastics in the soil, their sources and access routes. It focuses on the analysis of the accumulation, migration, and degradation of microplastics in the soil, as well as the interaction with metal and organic pollutants and their environmental effects; expounds the impact of microplastics on soil organisms and soil quality and ecological risks and discuss the exposure pathways and potential human health risks of microplastics in the soil are discussed. Finally, the future direction and focus of the research on microplastics in the soil environment are prospected. It is expected to provide information and scientific guidance for a comprehensive understanding of the present and future of soil environmental microplastics research.

Keywords: soil environment, microplastics, environmental risk, research progress.

1. Introduction

At present, the main new pollutants in the world include environmental endocrine disruptors, perfluorinated compounds and other persistent organic pollutants, antibiotics, and microplastics [1]. The recycling rate of plastics is low, and the plastics that enter the environment can be further broken and decomposed into microplastics through long-term physical, chemical, and biological effects. These may pollute the soil environment, affect the growth of animals and plants, the reproduction of microorganisms, and even the migration of groundwater. In addition, microplastics in the environment affect human health through the atmosphere and food chain. At present, most studies on microplastic environmental processes and ecological risks focus on aquatic environment. Although more and more studies have begun to focus on the terrestrial environment in the past two years, the proportion of microplastics in soil is not high, which still needs more attention [2]. Microplastic pollution in soil has become a research hotspot in the global environmental community in recent years. Based on the latest research on microplastics, the paper summarized the abundance and distribution, sources, and pathways of microplastics in soil environment, as well as potential environmental and human health risks, and prospects for future research.
2. Distribution and source of microplastics in soil

2.1. Abundance and distribution of microplastics

Compared with the water environment, there are fewer reports on the pollution of microplastics in the soil. Different soil textures and utilization types will cause differences in the abundance of microplastics in the soil [3]. At present, investigations of microplastic pollution in soil have been successively carried out at home and abroad.

Large numbers of investigations and studies have shown that the physical and chemical properties, use, time, and other factors of the soil itself affect the difference in the plugging of microplastics. The abundance of microplastics in the soil increases with the decrease of particle size, and the spatial difference is large. The abundance of microplastics decreases with the increase of soil depth. There are differences in the abundance and distribution of microplastics in soils with different land use patterns. The abundance of microplastics in the soil in the eastern coastal zone of China is 1.3-14712.5 ind·kg⁻¹, of which microplastics with a particle size of less than 1mm account for about 60%. The average abundance of microplastics in farmland soil in Shanghai is 16.1±3.5 ind·kg⁻¹, which is significantly lower than the abundance of microplastics in the surface layer of greenhouse soil of 78.00±12.91[4]. Microplastics with a particle size of less than 1 mm account for 48.79%. The abundance of microplastics in lakeside wetlands and facility farmland in the Dianchi Lake area of Yunnan is as high as 7100-42960 ind·kg⁻¹, with an average of 18 760 ind·kg⁻¹, of which microplastics with a particle size of less than 1 mm account for 95 %.

In general, the survey data of microplastics in soil is relatively small, and the abundance of microplastics in soils varies greatly in different regions, different land uses and socioeconomic levels. Analyze the reasons [5]. In addition to the land use methods, the extraction and detection methods of microplastics are not uniform and there is a non-negligible relationship, and the measurement methods of microplastics content also exist (ind·kg⁻¹) and quality (mg·kg⁻¹) are different method.

2.2. Sources and pathways of microplastics in soil

The application of chemical fertilizers, agricultural film, sewage discharge, atmospheric sedimentation, and leakage of solid waste landfill leachate are collected into the soil environment through certain channels, and they are important sources of soil microplastics. To improve agricultural output and product quality, large numbers of plastic films are used in agricultural production. According to statistics, the global agricultural mulch film will exceed 3 million tons in 2021, and China is a major mulch film manufacturer and consumer. In 2017, the use of mulch film in China reached 1.437 million tons, covering an area of 18.65 million hectares, but the recovery rate of mulch film was less than 60%. The residue of agricultural film is an important way for the accumulation of microplastics in the soil. The plastic film accumulated in the soil can be split into microplastics or even nanoplastics under the action of light and microorganisms [6]. Among the vegetable greenhouses on the outskirts of Shanghai, the surface soil with mulching film used for more than ten years has the highest abundance of microplastics.

In the process of sewage treatment, microplastics accumulate in sludge and enter the soil through resource utilization of sludge. Long-term agricultural use will inevitably aggravate the pollution of microplastics in the soil. The abundance of microplastics in sludge samples from 28 sewage treatment plants in 11 provinces in China ranged from 1 600 to 56 400 ind·kg⁻¹, with an average of 22700±12100 ind·kg⁻¹. The number of microplastics entering the environment through sludge every year in China is estimated to be as high as 1.56×10¹⁴. The abundance of microplastics in the soil with continuous sludge application is significantly higher than that in the surrounding soil without sludge. In addition, the composted organic manure of livestock and poultry manure is an important fertilizer in the agricultural production process and is especially widely used in facility agriculture. At present, the size of the plastic fragments detected in organic fertilizers is greater than 0.5 mm, and the microplastics with a particle size of less than 0.5 mm are not yet known. However, investigations show that the abundance of plastic fragments with a particle size greater than 1 mm in organic
fertilizers is 14 to 895 ind·kg\(^{-1}\), and most countries have not paid attention to the problem of microplastic pollution in organic fertilizers \(^7\). China is a major application of organic fertilizers, and the actual amount of commercial organic fertilizers accounts for 88.4\% of production. In addition, domestic sewage and textile washing wastewater are not discharged up to standards, illegal dumping and improper disposal of garbage, plastic products and car tires, and sea tidal movement are all sources of microplastics in the soil.

3. Microplastic pollution process and environmental effects

3.1. Release of microplastics and adsorption of pollutants
Plasticizers, antioxidants, heat stabilizers, lubricants, etc. are commonly used additives in plastic processing and production. As a stabilizer in the manufacture of polyvinyl chloride (PVC) plastics, organotin can be released from the plastic through photochemical weathering. Microplastics can release phthalates, oligomers, styrene, etc., thereby affecting the diversity of microorganisms in the soil, and even migrate to food through the food chain.

Microplastics can be used as carriers of environmental pollutants to adsorb antibiotics and persistent organic pollutants. The adsorption capacity and adsorption mechanism are related to the types of plastics. The residual amount of chlorpyrifos and chlorpyrifos on the film even reached more than 70 times the residual amount in the soil. The adsorption capacity of microplastics is significantly related to their hydrophobicity \(^8\). Electrostatic interaction, hydrogen bonding and cation bridging mechanisms will also affect the adsorption of organic pollutants by microplastics. Heavy metals can also be adsorbed by microplastics. The microplastics extracted from the soil contain different concentrations of Cu, Cd and Pb, and the aging of high-density polyethylene, polyvinyl chloride and polystyrene microplastics can adsorb Cu and Zn in increase capacity.

3.2. The accumulation and migration process of microplastics
The physical blockage of the soil can accumulate microplastics that enter the soil through various channels. The physical and chemical properties of soil affect the accumulation of microplastics, and the retention rate of microplastics is directly proportional to the content of Fe or Al oxides. Due to the low oxidation and light shielding effect, the degradation efficiency of microplastics in the soil environment is low and the residual time is long. Microplastics will migrate horizontally and vertically in the soil. The wind force causes the microplastics to migrate horizontally over long distances. Rain affects the longitudinal migration of microplastics in the soil. The microplastics that have migrated underground can further enter water bodies and groundwater through erosion and soil flow \(^9\). The activities of animals in the soil and the growth of plant roots promote the horizontal and vertical migration of microplastics.

3.3. Weathering and degradation process of microplastics
The long-term accumulation of microplastics in the soil will inevitably be weathered and degraded. Long-term weathering causes the surface of microplastics to gradually age and crack into smaller microplastics or even nanoplastics, enhancing their environmental mobility. Weathering degradation changes the morphology of microplastics, forming many persistent free radicals and active oxygen on the surface. Microorganisms play an important role in degradation, and polyethylene (PE) degrading bacteria have received extensive attention \(^10\). The hydrolase and oxidoreductase produced by microorganisms will accelerate the degradation of PE. The application of nitrogen and phosphorus fertilizers can improve soil fertility and change the vitality of soil microorganisms, thereby promoting the degradation of microplastics in the soil.
4. Exposure of microplastics in soil environment and potential human health risks

4.1. Respiratory exposure and food chain transmission of microplastics
The wind force makes the microplastics float into the air along with the dust on the ground and can be inhaled into the lungs by the human body. It is estimated that the human lungs are exposed to 26 to 130 air microplastics every day. According to the estimation of the concentration of microplastics in the dust in 39 major cities in China, the range of plastic fibers and particles ingested by people of different ages is 64.1~889 ind·kg⁻¹·d⁻¹ and 8.44~119 ind·kg⁻¹·d⁻¹ [11]. Food chain enrichment transmission is an important way for microplastics exposure. The absorption and accumulation of microplastics by wheat and lettuce indicate that microplastics may be passed into the food chain through plants. There are also microplastics in salt, beer, and drinking water. Studies have shown that a single tea bag steeped at high temperatures (95°C) can release approximately 11.6 billion microplastics and 3.1 billion nanoplastics [12].

4.2. Potential human health risks of microplastics
Studies have found that continuous ingestion of plastic fibers through the respiratory tract can trigger lung inflammation, resulting in decreased immunity and possibly cancer. Microplastics can affect the immune system of mammals (mice), causing oxidative stress, neurotoxicity, cytotoxicity, and chronic toxicity. Mouse liver, kidneys and intestines can accumulate microplastics, and at the same time cause a series of adverse reactions in the liver and induce intestinal shielding dysfunction. In vitro experiments have shown that polystyrene microplastics can induce human lung epithelial cells to produce reactive oxygen species, resulting in cytotoxicity and inflammation [13]. Microplastics may not only pose risks to the human body, but also the additives and other adsorbed pollutants carried by the microplastics may also pose health risks in the body.

5. Research prospect
Due to the complexity of soil environment and the lack of uniformity in the detection and identification methods of microplastics, the chemical properties of microplastics remain to be confirmed, and the environmental behavior and potential risks of microplastics in soil need to be further studied. In the future, it’s necessary to carry out the characteristics, occurrence characteristics, migration and transformation characteristics, environment risk, and health risks of microplastics, etc., to make countermeasures for the reasonable control of microplastics.

(1) Drawing on the experience of chemicals control added to international conventions, microplastics governance is integrated into the environmental management system of chemical substances, and incentives for microplastics control are studied in conjunction with emission permits and mandatory cleaner production audit systems.

(2) Establish a microplastics early warning mechanism to monitor the health of key areas, industries and populations and carry out environmental risk assessment.

(3) Microplastics and traditional pollutants will coexist for a long time, developing rapidly biodegradable materials that can replace traditional film, strengthening the monitoring and management of the whole process of film production, utilization, recycling, and disposal, and reducing soil microplastic pollution from the source.

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References
[1] Chen Y L, Sun Ke, Han L F, et al. Separation, Identification, and Quantification Methods in Soil Microplastics Analysis: A Review[J]. Acta Pedologica Sinica, 2021, DOI: 10.11766/trxb202012070566.
[2] Yang J, Li L Z, Zhou Q, et al. Microplastics Contamination of Soil Environment: Sources,
Processes and Risks [J]. Acta Pedologica Sinica, DOI: 10.11766/trxb202006090286.

[3] Li P F, Hou D Y, Wang L W, et al. (Micro)plastics Pollution in Agricultural Soils: Sources, Transportation, Ecological Effects and Preventive Strategies [J]. Acta Pedologica Sinica, 2021, DOI: 10.11766/trxb202007190402.

[4] Zhang J J, Chen Y H, Wang X X, et al. A Review of Microplastics in Soil Environment [J]. Chinese Journal of Eco-Agriculture, 2020, DOI: 10.13930/j.cnki.cjea.200915.

[5] Wang Z C, Meng Q, Yu L H, et al. Occurrence characteristics of microplastics in farmland soil of Hetao Irrigation District, Inner Mongolia [J]. Transactions of the Chinese Society of Agricultural Engineering, 2020, 36(3):204-209.

[6] He D F, Luo Y M, Lu S B, et al. Microplastics in soils: Analytical methods, pollution characteristics and ecological risks [J]. TrAC Trends in Analytical Chemistry, 2018, 109:163-172.

[7] Hodson M E, Duffus-Hodson C A, Clark A, et al. Plastic bag derived-microplastics as a vector for metal exposure in terrestrial invertebrates [J]. Environmental Science & Technology, 2017, 51(8):4714-4721.

[8] Yang F, Li R, Cui Y, et al. Utilization and develop strategy of organic fertilizer resources in China [J]. Soil and Fertilizer Sciences in China, 2010(4):77-82.

[9] Luo Y M, Zhou Q, Zhang H B, et al. Pay attention to research on microplastic pollution in soil for prevention of ecological and food chain risks [J]. Bulletin of Chinese Academy of Sciences, 2018, 33(10):1021-1030.

[10] Lian J P, Shen M M, Liu W T. Effects of microplastics on wheat seed germination and seedling growth [J]. Journal of Agro-Environment Science, 2019, 38(4): 737-745.

[11] Zhang J J, Wang L, Kannan K. Polyethylene terephthalate and polycarbonate microplastics in pet food and feces from the United States [J]. Environmental Science & Technology, 2019, 53(20):12035-12042.

[12] Li B Q, Ding Y F, Cheng X, et al. Polyethylene microplastics affect the distribution of gut microbiota and inflammation development in mice [J]. Chemosphere, 2020, 244: 125492.