Meteorological and Environmental Research 2025, 16(4 – 5): 40 – 42

Pollution Status and Research Progress on Treatment of Microplastics in Soil

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Abstract As a new type of pollutant, microplastics have been widely detected in environments such as the ocean, lakes, atmosphere and soil. As a major sink for plastic waste, soil is particularly severely polluted. The current situation and hazards of microplastic pollution in agricultural soils in China are summarized, and the research progress of microplastic degradation and treatment is elaborated, providing a basis for further studies on soil microplastics.

Key words Microplastics; Pollution status; Treatment

DOI 10.19547/j.issn2152 – 3940.2025.04 – 05.011

Plastics and their products have become an essential part of production and daily life. Residues can decompose into microplastics through certain physical, chemical, biological and other processes, and enter the human body through direct or indirect channels, which may have adverse effects on lung function, immune system, *etc.* Its harmfulness is self-evident[1]. Microplastics (MPs) refer to plastic particles with a particle size of less than 5 mm. Currently, MPs found in the environment include polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS), polyamide (PA), polyester (PEst), *etc.* In 2022, the General Office of the State Council issued the *Action Plan for the Control of New Pollutants*, which clearly stated that MPs are a new pollutant that currently poses a threat to ecosystems and human health[2].

1 Current situation of microplastic pollution in soil

1.1 Single pollution caused by microplastics At present, microplastics are commonly detected in agricultural land, mainly from residual agricultural film or greenhouse film weathering and external inputs. External inputs mainly include microplastics produced by atmospheric deposition, agricultural irrigation, organic fertilizer application and other processes[3]. The types of microplastics vary in different regions or crop planting agricultural areas, and there are also significant spatial differences in abundance. The particle size of microplastics in different tillage layers also has different distribution patterns. Among them, the types of microplastics in Harbin farmland in Northeast China are PE, PP, PET, PS, PA, PMMA, *etc.*, mainly manifested as fibrous, fragmented, film like, and microsphere like, with an abundance of 198.32 – 1 002.61 n/kg. It is mainly caused by agricultural films and plastic products appearing around farmland[4]. The abundance of different soil layers varies in the greenhouse planting area of Guanzhong Plain in Shaanxi Province. The average abundance in the 0 – 10 cm of soil layer is 34.9 μg/g, while the content in the 20 – 30 cm of soil layer is 4.79 μg/g[5]. The types of microplastics in agricultural facility land in Beijing are PP, PE, RY, *etc.*, with an abundance of (440.00 ± 179.63) – (2 366.67 ± 347.21) n/kg. The shape of microplastics is mainly fragmented, and the colors are mainly white, transparent, and blue. Pollution is mainly caused by plastic film and greenhouse film, organic fertilizer application, agricultural irrigation, tying ropes, and packaging bags[6].

1.2 Microplastic composite pollution

1.2.1 Composite pollution of microplastics – heavy metals. Due to their small particle size, large specific surface area, and strong mobility, microplastics usually enrich heavy metals in various forms such as physical, chemical, or multi-layer adsorption. The adsorption capacity is mainly related to soil acidity, heavy metal content, and microplastic adsorption performance, and the adsorption performance is mainly affected by hydrophobicity and chemical bonding between cations and anions[7]. Research has shown that there is a significant correlation between the content of heavy metals such as Cr, Ni, As, Cd, Zn, Pb, Cu, Zn, and the abundance of microplastics. Microplastics inhibit the germination rate, stem and root growth, and fresh weight of plants[8]. The impact of different types of microplastics coexisting with heavy metals on soil crops varies greatly. Microplastics can alter the abundance and types of microorganisms in heavy metal contaminated soil, and can change the proportion of different valence states of heavy metals at different stages of plant growth, thereby promoting the absorption of heavy metals[9]. Huang *et al.* [10] demonstrated that microplas-

Received: July 6, 2025 Accepted: August 28, 2025

Supported by Hebei Geological Exploration Fund Project (13000024P00B04-410056L).

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tics can increase the accumulation of heavy metals in plants by studying the bioavailability of microplastic PE on Cd in soil.

1.2.2 Composite pollution of microplastics – persistent organic pollutants. Microplastics can adsorb persistent organic pollutants such as polybrominated biphenyls, polychlorinated biphenyls, organochlorine pesticides, polycyclic aromatic hydrocarbons, bisphenol A (BPA), petroleum hydrocarbons, *etc*[11]. Microplastics can interact with organic pollutants in soil through hydrophobic interactions, electrostatic forces, $\pi-\pi$ bonds, *etc.*, affecting their co-migration in soil, soil physicochemical properties and enzyme activity. Qu Zichao's team[12] found that PE-PHE composite pollution has a synergistic effect on increasing soil pH and reducing soil cation exchange capacity. PE-PHE composite pollution can synergistically promote the increase of soil organic matter content, and microplastics can activate soil catalase, dehydrogenase, and urease activities. Microplastics and organic pollutants also have varying degrees of impact on the growth of crops. Zhu Zhengyi *et al.* [13] studied the effects of three types of microplastics, namely polyethylene, polystyrene, and polyvinyl chloride, combining with benzo [a] pyrene on rice growth. The results showed that the combined pollution of microplastics and Bap had an interactive effect on rice seeds. Microplastics had a significant impact on rice seed growth, including inhibiting germination rate, vitality index, and germination speed, promoting germination potential and moisture content. The coexistence of Bap had a promoting effect on the vitality index, root length, shoot length, and moisture content of rice seeds, but its impact on germination potential was more complex.

2 Progress in governance research

The pollution situation of microplastics in soil is not optimistic, and its effective control is imperative. However, there is currently limited research on related governance, with a focus on microbial governance. The process of microbial degradation of microplastics in soil is relatively complex. Microorganisms that exist in nature or have been screened and cultured adsorb and colonize on the surface of microplastics, forming communities with special functions. These microbial communities can reproduce using microplastics as the sole carbon source. By secreting extracellular or intracellular targeted hydrolytic enzymes and oxidoreductases, chemical bonds in the structure are broken to form oligomers or monomers. The products are then transported to the microbial community cells to generate CO_2, CH_4, and H_2O or assimilate into microbial biomass through the β-oxidation pathway and tricarboxylic acid cycle, thereby achieving effective decomposition[14]. Microorganisms with the potential to degrade microplastics include bacteria and fungi, and different bacterial genera have specificity. Common bacterial genera include *Pseudomonas adaceae*, *Rhodococcus*, *Trichoderma*, *Bacillus*, and *Bacillus subtilis*, which can degrade polyethylene; *Bacillus*, *Rhodococcus*, white-rot fungi, *Candida albicans*, and other bacteria can degrade polypropylene; super thermophilic bacteria such as *Exiguobacterium* sp. YT2, *Serratia*, *Staphylococcus* and *Rhodococcus*, *Pseudomonas aeruginosa*, thermobacterium, *Bacillus*, and *Terrabacter* can degrade polystyrene microplastics; *Alcanivorax*, *Hyphomonas*, *Cycloclasticus*, *Pseudomonasaeruginosa* SWI36, *Bacillus thuringiensis* C15, *Bacillus albicans* PFYN01 can degrade polyethylene terephthalate (PET)[15]. In addition, Li Zelin *et al.* [16] constructed a highly efficient polyethylene degradation composite strain. Compared to individual fungi or bacteria, it showed a 3.3-fold improvement in degradation performance, with a degradation efficiency of up to 0.936 7 mg/d.

Although the products of microbial degradation of microplastics do not cause secondary pollution, their degradation rate is slow, and other metabolites produced during the process may have adverse effects on the physical and chemical properties of the soil environment[17]. In addition, current research on the degradation of microbial communities is mostly focused on laboratory environments. It is necessary to screen for native bacteria that can degrade specific microplastics with good performance and low requirements for growth environment and degradation conditions, actively construct efficient and controllable green microbial communities, and actively carry out field research.

3 Research prospects and directions

First, it should strengthen source control and guide the reduction of usage. Based on the fact that agricultural sources are the main input, it should actively advocate controlling the use of mulching, fertilization, and sewage irrigation in farmland to effectively reduce plastic input. It is necessary to clarify the sources and pollution levels of microplastics in soil in different regions, and to address them from the source, to provide data support for subsequent management.

Second, it should actively develop effective biodegradable plastics. At present, common biodegradable plastics include polylactic acid (PLAs), polyhydroxyalkanoates (PHAs), poly (3-hydroxybutyrate) (PHB), cellulose acetate esters (CAs), thermoplastic starches (TPSs), and polybutylene succinate (PBS)[18]. After a certain period of time, their chemical bonds break. Under suitable conditions, they are ultimately converted into substances such as carbon dioxide and/or methane, water, *etc.* Therefore, it is particularly important to actively develop efficient biodegradable plastics without secondary pollution.

References

[1] NUELLE M T, DEKIFF J H, REMY D, *et al.* A new analytical approach for monitoring microplastics in marine sediments[J]. Environmental Pollution, 2014, 184: 161–169.

[2] General Office of the State Council of the People's Republic of China. Action plan for new pollutant control[R]. Beijing: General Office of the State Council, 2022.

[3] ZHANG YJ, CHEN HM, WU LJ, *et al.* Soil microplastic contamination and agricultural safety: Sources, effects and removal [J]. Journal of Guizhou Normal University: Natural Sciences, 2024, 42(4): 31 – 43.
[4] YU QX, LIU S, MA LN, *et al.* Analysis on the occurrence characteristics and influencing factors of microplastics in Harbin agricultural soils [J]. China Environmental Science, 2023, 43(2):793 – 799.
[5] CHEN RL, CHEN YH, HUANG S, *et al.* Residues and accumulation characteristics of plastic fragments and microplastics in farmland soil of Guanzhong Plain, Shaanxi [J]. Chinese Journal of Eco-Agriculture, 2022, 30(10): 1649 – 1658.
[6] WU YM, WANG YP, WANG K, *et al.* Pollution characteristics and potential sources of microplastics in facility agricultural soil in Beijing[J]. Asian Journal of Ecotoxicology, 2022, 17(4): 333 – 344.
[7] BRENNECKE D, DUARTE B, PAIVA F, *et al.* Microplastics as vector for heavy metal contamination from the marine environment[J]. Estuarine, Coastal and Shelf Science, 2016, 178: 189 – 195.
[8] LIU Y, MA J, FENG BC, *et al.* Review on the transport behavior of microplastics and ecological effects of microplastics and its combined pollutant in soil[J]. Journal of Agro-Environment Science, 2025(3): 537 – 553.
[9] FAN WX, QIU CS, MU L, *et al.* Toxic effect on lettuce induced by the coexistence of nanoplastics and arsenic in the soil and the related metabolic mechanisms[J]. Journal of Agro-Environment Science, 2025(4): 899 – 908.
[10] HUANG F, HU J, CHEN L, *et al.* Microplastics may increase the environmental risks of Cd via promoting Cd uptake by plants: A meta-analysis[J]. Journal of Hazardous Materials ,2023, 448:130887 – 130894.
[11] XIE JF, ZHANG JE, WEI H, *et al.* Microplastic-based compound pollution in soil: An overview[J]. Ecology and Environmental Sciences, 2022, 31(12): 2431 – 2440.
[12] QU ZC, ZHAO BW, DENG AQ, *et al.* Effects of polyethylene microplastics and phenanthrene on soil properties and growth of ryegrass[J]. Environmental Chemistry, 2025(7): 2385 – 2398.
[13] ZHU ZY, SUN LJ, SUN YF, *et al.* Synergistic effects of microplastics and benzo[a]pyrene(BaP) on the germination of rice seeds[J]. Journal of Ecology and Rural Environment, 2024, 40(9): 1251 – 1259.
[14] HAN YJ, TENG Y. Research progress on ecological effects and microbial degradation of biodegradable plastics in soils[J]. Acta Pedologica Sinica, 2025.
[15] SZYMANEK I, CVEK M, ROGACZ D, *et al.* Degradation of polylactic acid/polypropylene carbonate films in soil and phosphate buffer and their potential usefulness in agriculture and agrochemistry[J]. International Journal of Molecular Sciences, 2024, 25(1): 653.
[16] LI ZL, XU ZH, XU LH, *et al.* Construction and degradation characteristics of high-efficiency polyethylene degrading composite microbial community[J]. Acta Agriculturae Universitatis Jiangxiensis, 2024, 46(2): 481 – 489.
[17] CHIGWADA AD, TEKERE M. The plastic and microplastic waste menace and bacterial biodegradation for sustainable environmental clean-up a review [J/OL]. Environmental Research, 2023, 231: 116110 – 116119.
[18] RAI P, MEHROTRA S, PRIYA S, *et al.* Recent advances in the sustainable design and applications of biodegradable polymers[J]. Bioresource Technology, 2021, 325: 124739 – 124750.

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[3] WANG XF. Research progress on sample treatment methods for benzene series in ambient air and fixed source exhaust gas[J]. Chemical Analysis and Meterage, 2025, 34(2): 125 – 131.
[4] WANG HY, ZHOU C. Determination of waste gas from stationary sources by solid phase adsorption – thermal desorption/gas chromatography – mass spectrometry benzene series[J]. Guangzhou Chemical Industry, 2025, 53(9): 133 – 135, 162.
[5] ZHAO Q. Determination of benzene series in ambient air by Tenax TA solid adsorption/thermal desorption combined with gas chromatography [J]. Shanxi Science & Technology of Transportation, 2020(3): 114 – 116, 127.
[6] LANG YD. Evaluation of uncertainty in determining BTEXs in ambient air by solid adsorption thermal desorption – gas chromatography [J]. Environmental Monitoring and Forewarning, 2016, 8(1): 31 – 34.
[7] BAN TT, ZHANG RY. Uncertainty evaluation of determination of benzene compounds in exhaust gas by gas bag sampling – direct injection – gas chromatography[J]. Polyester Industry, 2025, 38(3): 18 – 20.
[8] XIE X, WU Y, WANG T, *et al.* Determination of eight kinds of benzene in exhaust gas from stationary source by bag sampling – gas chromatography[J]. Environmental Science and Management, 2024, 49 (7): 106 – 109, 140.
[9] CAO Y, LI SF, ZHOU NF, *et al.* Exploration of two gas chromatography methods for determining standard samples of benzene compounds [J]. Laboratory Testing, 2025, 3(6): 104 – 107.
[10] WANG QQ. Study on the determination of benzene derivatives in fixed pollution source exhaust gas based on gas chromatography[J]. Papermaking Equipment & Materials, 2023, 52(5): 158 – 160.
[11] Ministry of Ecology and Environment. Stationary source emission: Determination of benzene and its analogies: Bags sampling/direct injection – gas chromatography (HJ 1261 – 2022)[S]. Beijing: Standard Research Institute of the Ministry of Ecology and Environment, 2022.
[12] Ministry of Environmental Protection. Environmental monitoring: Technical guideline on drawing and revising analytical method standards (HJ 168 – 2010)[S]. Beijing: China Environmental Science Press, 2010.