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THE SILENT INVADERS: MICROPLASTICS AND THE IMPENDING GLOBAL HAZARD

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Abstract:

Microplastic pollution has emerged as a global environmental challenge with potential risks to ecosystems and human health. One significant input pathway of microplastics into the environment is through compost, which is commonly used for soil amendment and agricultural purposes. The current research focuses to investigate the identification, quantification, and characterization of microplastics in different compost types. The study involves the collection of compost samples from various sources including composting plants and commercial composting facilities. Microplastic analysis was conducted using Fourier-transform infrared (FTIR) spectroscopy, which enables the identification of different types of microplastics present in the samples. The characterization of microplastics included assessing their size, shape color, and polymer composition. The findings of the research indicate the presence of microplastics in all compost samples analyzed. Microplastics of various types such as fibers, fragments, and films were identified through FTIR spectroscopy. The concentration of microplastics ranged from 3000 to 15000 particles/ kg of compost. Microplastic concentration varies among different types of compost based on their origins and raw materials. Compost from mixed waste facilities exhibits higher microplastic concentration as compared to compost made from separately collected organic waste. The results of the study highlight the need for research focusing on microplastic effects on the environment and how they transfer into the food chain. The study's outcomes provide crucial information to policymakers, waste management authorities, and compost producers to develop and implement measures to limit microplastic pollution in compost along with an urgent need to develop policies to address plastic pollution.

Introduction

Plastic waste accumulation has become a global concern, with serious environmental and health consequences. Microplastics, defined as plastic particles less than 5mm in diameter, have emerged as a widespread pollutant in a variety of ecosystems, including seas, rivers, and even terrestrial settings. While the existence of microplastics in aquatic systems has received extensive research, the potential contribution of composted organic materials, which are extensively utilized in agricultural practices, as a source of microplastics in agricultural soils has received less attention.

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Improper management of plastic waste has raised the concern about the presence of plastic material in the organic- waste derived compost due to the unplanned disposal of plastic materials in compost heaps. As composting is considered a sustainable solution for organic waste management and soil organic conditioning, it is important to investigate whether this eco-friendly practice accidently adding up microplastics into the agricultural soils. Microplastics contamination may have adverse effects on soil physical and chemical composition, plant growth, and ultimately ecosystem health.

The current research focus on collecting the existing body of knowledge on the possible role of compost as a microplastics source in agricultural soils. By critical examination of available research, we seek to evaluate the magnitude and prevalence of microplastic contamination in organic waste derived compost.

Transportation of microplastics into the Environment

The distribution of microplastics in marine environment have been investigated under numerous studies (Auta et al. 2017), but the information on microplastics contamination status in terrestrial environment is still lacking. There are different studies identified organic fertilizers contribution to the agricultural land contamination with microplastics.

Available data suggest that Microplastics enter the environmental compartments in two main ways. Primary microplastics from land enter the water bodies via runoff in form of plastic pellets, microbeads, and scrubbers that are manufactured as raw plastic materials (Browne et al., 2008; Arthur et al., 2009). While secondary microplastics enter the terrestrial or marine environment when larger plastic items undergo photo-oxidation and mechanical or biological degradation (Browne et al., 2008; Cooper and Corcoran, 2010; Cole et al., 2011, Thompson, 2015). The degradation process breakdown the larger pieces into smaller plastic fragments that are not visible to the naked eye. Since the first observation of microplastics in North American waters in the 1970s (Baechler et al., 2020), research has been focused on microplastics identification in larger water bodies; oceans, rivers, seas, and lakes, and the majority of studies focused on research and testing of microplastics and eco-toxicity on the aquatic ecosystem.

Microplastics contamination in Terrestrial Environment

In recent years, there has been an increased concern over the presence of microplastics in terrestrial settings, particularly in relation to the use of composted soil amendments produced in industrial facilities where plastic-based and plastic-coated organic feedstock may be present. Technically, it could be conceivable to stipulate that only certified biodegradable polymers can be carried to certain facilities, but in practice, this is hardly practicable. Microplastics found in agricultural soils may take many different forms, including fibers, fragments, films, and beads of multiple colors. In spite of the fact that polypropylene (PE), polyethylene (PE), polyvinyl alcohol (PVA), polyester (PES), and polyethylene terephthalate (PET) are the most frequent types of plastic polymers that are discovered in soils, other plastic polymers are also detected in large proportions (PET). It has been discovered that microplastics are present in the Forni glacier, which is located in the Italian Alps, and have been quantified (Ambrosini et al., 2019). According to the calculations, an average of 74.4 ± 28.3 particles per Kilogram is found in sediment samples. PES, PA (polyamide), PE, and PP were the types of polymers that were seen as the most abundant. According to the findings of the study, the microplastic count in

the glacier zone ranged from 131,000 to 162,000,000 particles. It is possible that human activities emit microplastics into the atmosphere, and these particles may be transported to higher altitudes (such as mountains) by the wind and accumulate there. Because when the snow melts at higher altitudes, accumulated microplastics may fall into the glacier zone and get trapped there.

Microplastics can infiltrate farms in a number of different ways. The most common source of microplastic exposure is the widespread use of plastic goods in farming, as well as the use of contaminated amendments or the introduction of microplastics from elsewhere (Xu et al., 2020). As a result of its usefulness in agriculture, plastic has become a managerial staple in the modern era. Plastic mulching, for instance, is widely used for warming soil, suppressing weeds, and maximising water efficiency. Plastic netting are also used to protect crops, and plastic pipes are used in the irrigation system. This material breaks down in the field due to abiotic processes such as sunlight, water, heat, oxygen, and physical forces like wind or ploughing (Crawford et al., 2017).

Organic Fertilizers as a source of microplastics

Organic fertilizers made from mixed waste sources are a potential source of microplastics in agricultural soils (Edo et al., 2021). However, even the organic fertilizer (compost) made from food waste and green waste collected separately can be contaminated with microplastics. The food waste in addition to food contents may also contain food packaging material and plastic bags that are thrown together into the organic waste container (Sundt et al., 2014), The Green waste compost might potentially contain microplastics from accidentally trapped plastic and disposal bags in green waste before the collection of waste. According to (Markowiz and Szymansks- Pulikowska, 2019), the residue of biodegradable and oxo-biodegradable bags remains in the finished compost along with organic waste after the composting process.

Diversion of food waste from landfills to composting and anaerobic digestion can reduce greenhouse gas emissions and recover energy in a significant form to be utilized. It also adds nutrients to the soil. There is a concern that compost prepared from food waste could transmit microplastics into agricultural soils due to the mixing of food waste with plastic packaging. (Schwinghammer et al., 2020) reported that the microplastics abundance in homogenized food waste which contained ~ 40 to 1400 ± 150 items/ kg of dry material. Another study reported the microplastics abundance to be 300,000 particles/ kg of dry weight in grocery waste from US (Golwala et al., 2021). Porterfield suggested there is a need to determine the potential entry pathways for microplastics into agricultural soils. The research on microplastics in soil amendments made from food waste is still in its early stages. The study focused over the abundance of microplastics in compost, food waste, and digestates as well as their effects on soil agricultural soils (Porterfield et al., 2022).

The use of sewage sludge as an organic fertilizer for soil conditioning is a common practice among various countries. Researchers in Chile examined the role of sewage sludge in the contamination of agricultural soils with microplastics and found that it has a significant role. Investigations were carried out over a period of ten years in a total of thirty-one agricultural locations. According to the findings of the study, one gram of soil included anywhere from 18 to 41 microplastic particles. The majority of the microplastics

discovered were fibers (90 and 97 percent in sludge and soil, respectively). The discovery of microplastics in soil samples sheds light on the role that sewage sludge plays in the contamination of soil microplastics (Corradini et al., 2019).

(Edo et al. 2021) in another study found microplastics in composted organic fractions of municipal solid waste (OFMSW) that were used in agricultural soils as a nutrient and organic matter source. The results of the study illustrated the abundance of plastic impurities in the range of 10-30 particles/ g of dry compost. The dominant shape of plastics was fibers with 25% of all particles of <500 µm and the concentration of fragments and fibers with <5 mm diameter was in the range of 5-20 items/ g of the dry weight of compost.. 94% of plastic items were represented by 5 polymer types that were polystyrene, polyethylene, polypropylene, polyester, acrylic polymers, and polyvinyl chloride.

The identification of the abundance of light-density microplastics contamination in two vegetable production systems was conducted in southeast Spain and the Netherlands. The agricultural soil selected from Spain used plastic mulch whereas in the Netherlands farmers applied compost for production. Other compost samples were obtained from two Dutch compost plants with compost from the MSW (municipal organic waste) facility and from greenhouse and garden waste. Results can be summarized as follows: Spanish soil contained 2242 ± 984 microplastic items/ kg whereas Dutch soil showed an abundance of 888 ± 500 items/ kg. Microplastics contamination was higher in compost samples collected from municipal organic waste than the ones collected from garden and greenhouse waste with an abundance of 2800 ± 616 items/ kg and 1253 ± 561 items of microplastics/ kg respectively (Schothorst et al., 2021).

A study was conducted in the Zhejiang province of China where two RDW (rural domestic waste) composting treatment stations were selected from two towns for sample collection. The study determined the abundance and characteristics of microplastics in RDW composting and how the composting process affects the microplastic composition. The abundance of microplastics in RDW compost products with the size range of 0.05-5 mm was 2400 + 358 items/ kg of dry weight. The dominant microplastics shape was fibers and films. While the most common polymer types were polyester, PP (polypropylene), and PE (polyethylene). More than 50% of the quantity was accounted by microplastics with a size of < 1 mm. The study showed that the last stages of composting comprise more microplastics with a size of < 1 mm and more foam microplastics were observed. Thus the study concluded that RDW compost was a substantial source of microplastics in soils (Gui et al., 2021).

Organic fertilizers are increasingly being identified as a source of microplastic buildup in agricultural soils. A Chinese study discovered an abundance of microplastics in organic fertilisers extensively used throughout the country. Organic fertilzsers were extracted from a range of feedstock, such as bacterial residues and livestock dung (cow, pig, goat, and chicken manure), among others. Microplastic abundance varied from undetectable particles to 2550 particles/kg, with an average value of 325 ± 511 particles/ kg and a detection frequency of 80.4%. The highest quantity of microplastics was found in Beijing City compound organic fertilzers (758 particles/ kg). According to the study's findings, the most common shape of microplastics discovered was films (39%), and white or

transparent color contributed 75.9% of all microplastics. Microplastics ranged in size from 1 to 3 mm and accounted for 55% of all microplastics. The study's findings suggested developing mitigation techniques to control microplastic input in farming soils (Zhang et al., 2022).

(Tan et al. 2022) conducted a studyon the presence of microplastics in organic solid wastes and their biologically treated products. The extraction, identification, and distribution of microplastics was studied in organic solid wastes including food waste, sludge, and livestock manure, and also in the biologically treated products of organic waste. The study also evaluated the ecological risks of microplatics. The results of the study showed that the microplastics abundance in the organic solid waste was highest in the sludge followed by food waste and livestock manure respectively. The main microplastic polymers identified were Polyethylene, polypropylene, and polyethylene terephthalate and the dominant shapes were fibers and films. The major microplastic colors in organic solid waste included black, blue, red, and green microplastics. The results indicated that after biological treatment of organic solid waste the microplastics exhibited cracks, bludges, holes or depressions, and degradation into further small fragments with greater ecological risks (Tan et al., 2022).

To improve soil fertility, the application of compost in agricultural fields is widely recommended. A study was conducted on the application of compost as a major input pathway of microplastics into agricultural soil. To determine the compost application effect on the plastic load of soil, the samples were collected from the soil amended with compost made of municipal bio-waste with 12 years of application. The microplastics stock in the plough layer of 0- 30 cm showed a range of 38.2 ± 55.5 Mil to 171.4 ± Mil particles/ ha while long-term compost trial fields represented microplastic load of 0- 64 particles/ kg (Braun et al., 2022).

Microplastic quantity and characteristics were discovered in the processed organic waste of Lithuanian waste management centers. The study concentrated on the qualitative and quantitative investigation of microplastics with a diameter of less than 50 µm. Microplastics were quantified using several types of compost samples. In autumn, stabilised organic waste (SOW) had the greatest average concentration of microplastics (17407 ± 1739 particles/ kg) while in winter, it had the lower concentration (15400 ± 1217 particles/ kg). According to the findings, even processed organic waste collected separately contains a considerable proportion of microplastics. Green compost samples had 6433 ± 751 particles/ kg in winter and 5733 ± 850 particles/ kg in autumn, whereas food compost had 4066 ± 658 particles/ kg in winter and 3783 ± 351 particles/ kg in autumn. Approximately 83.8-94.9% of discovered microplastics were 1 mm in size. The most common microplastics particles in compost samples were films, followed by fragments. The presence of microplastics in compost emphasizes the necessity of controlling both large and small microplastics in organic waste fertilizers (Sholokhova et al., 2021)

The current study aimed at investigating the abundance of microplastics in different types of composts. The compost products were collected from composting plants and various composting facilities. The main compost types included compost made of organic waste collected from mixed solid waste facilities, food waste compost and green

waste compost. All the compost types undergo a similar preparation procedure that included drying, sieving and weighing. The samples were then digested using H_2O_2 overnight at 60ºC and then dried overnight at room temperature. Followed by digestion, density separation was done through NaCl. The samples were then filtered to obtain microplastics over a folter paper for further analysis. Microplastics quantification was done under setereomicroscope, for polymer identification of microplastics samples were observed under Fourier-transform Infrared Spectroscopy (ATR-FTIR).

The results of the current study depicts that sufficient amount of microplastics were present in all compost types. The highest number of microplastics were present in the compost collected from mixed waste collection facility followed by food waste compost and green waste compost. The microplastics ranged from 3000 mp /kg to 15000 mp /kg. The prominent shapes of microplastics were fibers, fragments and films while the microplastic sizes ranged from 50 µm to 5mm. The dominant polymer types of microplastics were Polyethylene (PE), Polystyrene (PS), Polyethylene terephthalate (PET), Polypropylene (PP), Polyurethane (PU), and Polyvinyl Chloride (PVC).

Source	MP conc.	Size Range	Polymer Type	Method used	Reference
Compost	3000-15000 particles /kg	50µm- 5mm	PE, PP, PS, PET, PU, PVC	Density separation using NaCl, Digestion through H_2O_2, identification- Stereomicroscope, analysis- ATR-FTIR	Current Study
	28 ± 14 plastic items/kg	<1 mm, 1–5 mm	PE, PS, PET, PVC	Density separation using $ZnCl_2$, SOM removal using H_2O_2, analysis- light microscope,	Braun et al. 2021
	43.8 ± 16.2 particles/ kg	<2 mm, 2–5 mm	PES, PE, PP, Rayon	/	Yang et al. 2020
	11–895 particles/kg	1–5 mm	PS, PES, PE, PP, PET, PVC, PUR, PVDC, PA	Isolation-distilled water and 30% filtered ethanol, identification- Stereomicroscope, analysis- ATR-FTIR	Weithmann et al. 2018
	888±500 items/kg	30 µm—2 mm	PE, PP,	Extraction and Floatation, Identification- Stereomicroscope, analysis- FTIR	Van Schothorst. 2021
	2400±358 items/kg	50 µm—5 mm	PS, PP, PE	Identification- Stereomicroscope, analysis- FTIR	Gui et al. 2021
	10-30 items/kg	<1mm	PP, PS, PE, PVC, Polyester, acrylic polymers	SOM removal using H_2O_2 , Density separation using $ZnCl_2$, stereomicroscope, analysis-FTIR	Edo et al. 2022

Transportation of microplastics into the food chain

In 2017, the first study on the prevalence of microplastics in the food chain was undertaken in the southeast of Mexico. Microplastics and macroplastics were studied for their potential to enter the food chain from soil-dwelling organisms. Researchers studied how micro- and macroplastics moved from the soil to the chickens in a Mayan home garden where waste management was prevalent. Soil, earthworms, chicken faeces,

crops, and gizzards were examined for their potential to transmit micro- and macroplastics to humans. Microplastics were found at increasing rates of 0.87 ± 1.9 particles / kg in soil, 14.8 ± 28.8 particles/ kg in earthworms, and 129.8 ± 82.3 particles/ kg in chicken faeces, respectively. Approximately 10.2-13.8 microplastic particles per kilogram were discovered in chicken gizzards. From an average of 45.82 microplastic particles per gizzard, the amount of microplastic particles discovered in the crops ranged from 11 to 15. The research shows that both small and large plastic particles can go up the food chain from the ground (Huerta Lwanga et al., 2017).

Grazing on fields that had plastic mulch applied was found to transfer microplastics into the sheep's faeces, according to research done in the Murcia region of Spain. The purpose of the research was to determine how much microplastics were delivered to cattle through grazing on agricultural soil where plastic mulch had been utilized. The study found that there were two times fewer particles per kilogram in the soil as there were in the sheep feces. The results showed that the sheep consumed microplastics that were found in the soil. Sheep that have grazed in one area that had microplastics may have spread the contamination to the next field they grazed. According to the research, a flock of one thousand sheep might be responsible for the movement of 106 particles per hectare every year. According to the results of the study, microplastics can move up the food chain from the soil to the animals and then to a higher trophic level if plastic is applied to the soil in any way (Beriot et al., 2021).

Effects of microplastics on soil properties

Zhang et al. (2022) state that soil fauna play a crucial role in ensuring the continued health and diversity of soil. Despite the fact that there has been no comprehensive study of soil fauna's response to microplastics, but they can be ingested by animals living in the soil, which might have a variety of negative impacts, such as diminished nutrient absorption, oxidative stress, false satiety, intestinal injury, and more. The microplastics' fate in soil can be affected further by the activity of soil fauna, which can break down the plastics and move the fragments about (Zhang et al., 2020).

This research is helpful for tracing the source of plastics in compost and establishing restrictions on the content of plastics in organic waste fertilizers since it reveals the existence of microplastic contamination in various types of compost. Further research on the sources of microplastics in agricultural soil and the destiny of microplastics in the food chain would be greatly aided by the findings of this study.

Conclusion:

The research studies has identified that compost is a primary source of microplastics in agricultural soil systems. Although plastic mulching films and sewage sludge have been identified a far and wide microplastic sources. Compost from mixed solid waste facilities receives attention due to the potential input source of microplastics in soil ecosystems as the highest amount of microplastics were observed in MSW compost. The reason of which incorporates the improper handling and management of solid waste at the treatment facilities. Therefore it is urgent to conduct further research over the fate and vector transport behavior of microplastics in compost to obtain the comprehensive knowledge about the detrimental impact of compost use. . Hence, it is important to

formulate the fertilizers Regulation and establish limitations on the concentration of microplastics not only of large but also small sizes in order to control land pollution.

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