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Preliminary results on microplastic pollution from agricultural soil in Vietnam: Distribution, characterization, and ecological risk assessment

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ABSTRACT

Microplastics (MPs) have been extensively studied in aquatic systems; however, their presence in general agricultural systems and in particular, soil still needs comprehensive understanding. This study conducted a field survey at 25 sites to investigate the abundance of MPs in agricultural soil. The MPs in these soil samples were separated using sieves and filters by the density separation method with NaCl solution (d = 1.2 g/cm^3). The density of MPs in agricultural soils ranged from 1,700 items/kg to 38,800 items/kg, with an average of 11,716 ±10,726 items/kg. The black-colored MPs were found to be dominant, followed by white, purple, red, and blue. The fibers represented most of the MPs' shapes observed in this research (77.9±17.4%). MPs in agricultural soil samples were tiny particles with sizes of <1,000 µm and 1,000-2,000 µm. A significant difference was observed in the concentration of MPs in locations near and far from residential areas and manufacturing facilities. The average concentration of MPs in the soils adjacent to the residential and manufacturing facilities and near the agricultural solid waste collection sites was 21,471±12,729 items/kg and 20,188±4,403 items/kg, much higher than in distant these locations at 4,418±1,573 items/kg. These results suggest that domestic, industrial, and agricultural activities could contribute to MP pollution in agricultural soil. The ecological dangers MPs pose in terrestrial and aquatic environments have drawn much attention from the scientific community. This work represented the first effort to comprehend the ecological risk of MPs on selected samples of Vietnamese agricultural soil. According to the Pollution Load Index (PLI) values, most agricultural soil samples in this study were contaminated with MPs at hazard level IV. The potential ecological risk index (PERI) values of agricultural soil samples from nearby residential, industrial, or agricultural solid waste areas indicated a higher ecological risk.

Keywords: agricultural soil, ecological risk, farmland, microplastic, polymer.

1. Introduction

Plastic products have been conveniently used and likely indispensable in our daily lives for decades. Plastic production and consumption have been increasing significantly since the 1950s (Monteiro et al., 2018). In 2020, approximately 367 million

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*Corresponding author, Email: duongthuy0712@gmail.com tons of plastic products were consumed (Plastics Europe, 2021). If plastics are not recycled and disposed of properly, they can linger for ten to hundreds of years. Under the influence of abiotic factors (light, temperature, air, water, external force, etc.) and biological factors (microorganisms), plastics in the environment can degrade into small particles of different sizes, such as macro- (> 25 mm), meso- (5–25 mm), micro- (< 5 mm), and nano plastics (< 0.1 μm) (Phuong et al., 2022).

Plastic pollution in agricultural fields has received increasing attention because plastic products are widely used in agricultural practices, such as cultivation, fertilization, and mulching. Furthermore, sewage sludge, compost, and wastewater irrigation applied in agriculture, contribute to the inputs of MPs into agricultural soils (Ding et al., 2020). It has been estimated by Weber and Opp (2020), 14% of the total plastics released into the environment go into agricultural soils. These plastics are broken up and degraded into smaller plastics under physical, chemical, and biological actions in agricultural soils. Some plastic particles contribute many MPs to soils, while others are continuously enriched in the food chain. Agricultural soils are regarded as the most significant MP sink in terrestrial ecosystems. High concentrations of MPs have been observed in several agricultural sites, such as agricultural surface soils in Shanghai, China (80–100 items/kg); Wuhan, China (320−12,560 items/kg); and floodplain soils in Switzerland (up to 593 items/kg) (Liu et al., 2018; Scheurer and Bigalke, 2018; Chen et al., 2020). Microplastics in the soil can absorb other substances, such as persistent organic pollutants (POPs), heavy metals, antibiotics, and pesticides (Ding et al., 2020). With their small size and associated toxic substances, MPs can mix into food and cause dangerous effects on biological organisms (Avio et al., 2015). Microplastics have a detrimental effect on soil and adversely influence terrestrial systems, which shows the necessity for preventative and mitigation methods. However, prior research has mainly focused on microplastic pollution in marine and freshwater environments. To our knowledge, understanding MPs in soil, especially agricultural soil, still needs to be improved (van den Berg et al., 2020). Besides, exploring pollution characteristics and the ecological risk assessment of MPs in the soil remain significant challenges (He et al., 2018). Therefore, it is crucial to focus efforts on evaluating the ecotoxicity risk of MPs to have a comprehensive understanding of the potential danger when organisms consume them. In the present study, agricultural soil samples were collected from 25 different sites located in three provinces in the northern part of Vietnam. The main goals were to (i) investigate MP abundance in agricultural soil samples; (ii) characterize the shape, size, color, and polymer type of MP; and (iii) provide a comprehensive evaluation of the potential risk of MP to soil ecosystems. The study provides a baseline for the area and contributes to databases on microplastic pollution in the agricultural field.

2. Materials and methods

2.1. Sampling location

A sampling design was carefully devised to collect diverse samples that reflect various land-use types. Soil samples were obtained during mid-season cover crops in 2022 to assess the level of MP in agricultural soil. The soil samples represented various land-use types and were collected, including vegetable soils (n=4), paddy soils (n=10), flower soils (n=7), and fallow soils (n=4). A total of 25 samples were taken in three provinces, including Bac Ninh, Ha Nam, and Ha Noi, with the locations of the sampling sites shown in Table 1. Each sampling location was carefully selected to represent a highly representative level of MP contamination.

Table 1. Information on agricultural land sampling sites

Sampling sites	Type of agricultural land	Sampling location information	Longitude	Latitude	Sampling sites	Type of agricultural land	Sampling location information	Longitude	Latitude
D1	Paddy soil	far from residential areas and manufacturing facilities	21.16	106.00	D14	Vegetable soil	near the agricultural solid waste collection site	20.97	105.75
D2	Paddy soil	far from residential areas and manufacturing facilities	21.15	106.00	D15	Paddy soil	far from residential areas and manufacturing facilities	20.80	105.77
D3	Paddy soil	near the agricultural solid waste collection site	21.13	105.96	D16	Fallow soil	far from residential areas and manufacturing facilities	20.79	105.78
D4	Vegetable soil	near the agricultural solid waste collection site	21.14	105.96	D17	Fallow soil	far from residential areas and manufacturing facilities	20.78	105.78
D5	Flower soil	far from residential areas and manufacturing facilities	21.10	105.69	D18	Paddy soil	near the open-air plastic waste dump	20.78	105.77
D6	Flower soil	far from residential areas and manufacturing facilities	21.10	105.66	D19	Paddy soil	near weaving and dyeing village	20.72	105.76
D7	Flower soil	far from residential areas and manufacturing facilities	21.10	105.67	D20	Paddy soil	near the textile factory	20.71	105.76
D8	Flower soil	far from residential areas and manufacturing facilities	21.09	105.69	D21	Fallow soil	near weaving and dyeing village	20.71	105.76
D9	Flower soil	far from residential areas and manufacturing facilities	21.09	105.68	D22	Paddy soil	near weaving and dyeing village	20.71	105.76
D10	Flower soil	far from residential areas and manufacturing facilities	21.09	105.64	D23	Vegetable soil	near the agricultural solid waste collection site	20.53	105.91
D11	Flower soil	far from residential areas and manufacturing facilities	21.08	105.64	D24	Paddy soil	far from residential areas and manufacturing facilities	20.47	106.04
D12	Fallow soil	near residential market areas and the open-air solid waste dump	20.99	105.78	D25	Paddy soil	far from residential areas and manufacturing facilities	20.42	106.04
D13	Vegetable soil	near residential areas and the open-air solid waste dump	20.98	105.80					

2.2. Sampling method and sample analysis

To obtain a representative sample, approximately 1 kg of soil per sample from three places, randomly selected (1mx1m plots) within each agricultural site was collected (all visible debris and stones were removed) using a stainless-steel soil sampler, thoroughly homogenized. Samples were transported to the laboratory in aluminum foil bags and stored at -20°C for further analysis. The sub-collected agricultural soil samples were dried at 40°C for 72 hours and then filtered by a fine net of 1 mm to reject unnecessary fragments, including tree covers, leaves, and plastics with a size > 1 mm. Ten grams of dried soil samples were placed in a 250 mL cup, then filled with 30% H_2O_2 for 4-6 hours to remove organic substances. A saturated salt solution (NaCl, 1.2 g/cm^3) floated MPs. This step was repeated five times for each sample to ensure complete MP extraction. After flotation, the solution was filtered through a GF/A filter (pore size 1.6 μm) using a glass filter. Filter papers were kept in sterile petri dishes until examined under a Leica MZ12 microscope to determine the size, morphology, and color. Based on GESAMP's recommendations, this study only focused on MPs with a minimum length of 300 μm to 5,000 μm for fiber and 45,000 μm^2 to 2,500,000 μm^2 for fragments. The analytical conditions were implemented following the procedure described in a recently published paper (Strady et al., 2021). In the reflection mode, MP types were identified on the filters using a Fourier transform infrared microscopy system (μFT-IR; Spotlight 200i FT-IR microscopy system, PerkinElmer). Each spectrum was recorded after 8 accumulations ranging from 600 to 4,000 cm^{-1}, and the whole filter surface was inspected with each single detected particle. Each obtained spectrum was then compared to the polymer database (Perkin Elmer Polymer Database), and the type of plastic was determined when the research score was higher than 60% (Phuong et al., 2018).

2.3. Pollution Load Index (PLI)

An integrated pollution load index (PLI) was calculated based on Tomlinson et al. (1980) to assess the degree of MP pollution in the agricultural soil samples. PLI at each location is related to MP concentration factors (CF$_i$), as given below:

$$CF_i = \frac{C_i}{C_0}$$

$$PLI = \sqrt{CF_i}$$

In the formula, i represents the sediment sampling site, C_i is the MP abundance at site i (items/kg), and C_0 is the background MP concentration (items/kg). Due to the lack of available background data, a reference background of 4.94 (items/kg) weight was adopted from Cao et al. (2021).

2.4. Potential ecological risk index (PERI)

The Potential Ecological Risk Index (PERI) was also used to assess the degree of contamination of MPs in agricultural soil (Peng et al., 2018). The equations used to calculate the PERI were as follows:

$$T_{ri} \;\; = \sum_{n=1}^{n} \frac{P_n}{C_i} S_n$$

$$PERI_i = T_{ri} \, . CF_i$$

Where: the toxicity coefficient (T_{ri}) represents the toxicity level and biological sensitivity. The toxicity coefficient is the sum of the percentage of specific polymers in the total sample (P_n/C_i) multiplied by the hazard score of plastic polymers (S_n). Where P_n is the polymer percentage in each sampling site, S_n is the target polymer hazard score, and the S_n scores for the specific polymer types were as follows: PE (Polyethylene): 11, PP (Polypropylene): 1, PS (Polystyrene): 30, Polyester: 1117; PVC (Polyvinyl chloride): 10001; PU (Polyurethane): 13844; Acrylic: 230 (Lithner et al., 2011).

Table 2. Grading standards of assessment indicators (Ranjani et al., 2021)

PLI	Hazard category	PERI	Risk category
<10	I	<150	Minor
10-20	II	150-300	Medium
20-30	III	300-600	High
>30	IV	600-1,200	Danger
		>1,200	Extreme danger

3. Results and discussion

3.1. Abundance of MPs in agricultural soils

MPs were found in all agricultural soil samples, ranging from 1,700 to 38,800 items/kg, with a mean of 11,716±10,726 items/kg. The highest MP concentration observed in this study was 38,800 items/kg (Fig. 1), much lower than those found in vegetable soil in Wuhan city (160,000 items/kg), and vegetable soil near Dian Lake, China (7,100-42,960 items/kg) (Zhou et al., 2019; Zhang and Liu, 2018). Furthermore, the maximum MP concentration in this study was much higher than in other previous reported investigations (Table 3), such as the concentration of 160 ± 93 items/kg in rice-paddy soils in Korea (Kim et al., 2021) and 0-217.8 items/kg in farmland samples in northern Germany (Harms et al., 2021). The average MP concentration in the four soil types was also varied: 4,400-38,800 items/kg in the paddy soil samples, 15,250-23,800 items/kg in the vegetable soil samples, 1,700-5,300 items/kg in the flower soil samples, and 3,200-35,100 items/kg in the fallow soil samples. The highest average MP concentrations were found in vegetable soil samples (13,885±11,485 items/kg) and paddy soil samples (18,888±3,114 items/kg). It could be seen that the abundance of MPs in paddy, vegetable, and fallow soils was significantly higher than in flower soil; the difference was significant ($p < 0.05$).

Several studies also reported the prevalence of MPs in paddy, vegetable, and maize soils (Yu et al., 2021; Cao et al., 2021). There were significant differences in the MP concentrations in agricultural soil samples near residential areas and manufacturing facilities, agricultural solid waste collection sites, and locations farther away from these areas. The average MP concentration in agricultural soils (D12, D13, D18, D19, D20, D21, and D22) near residential areas and manufacturing facility sites was 21,471±12,729 items/kg. And the average MP concentration in agricultural soils near agricultural solid waste collection sites (D3, D4, D14, and D23) was 20,188± 4,403 items/kg. At these points, the higher concentration of MPs in agricultural soils near residential areas, manufacturing facilities, and agricultural solid waste collection sites, could be attributed to the proximity of plastic waste storage sites near textile dyeing villages, textile factories, or agricultural waste gathering places. These values were much higher than the average concentration of MPs at the remaining points of 4,418±1,573 items/kg. This data suggested that human littering and industrial activities might be among the direct causes affecting the distribution of MPs in agricultural soil.

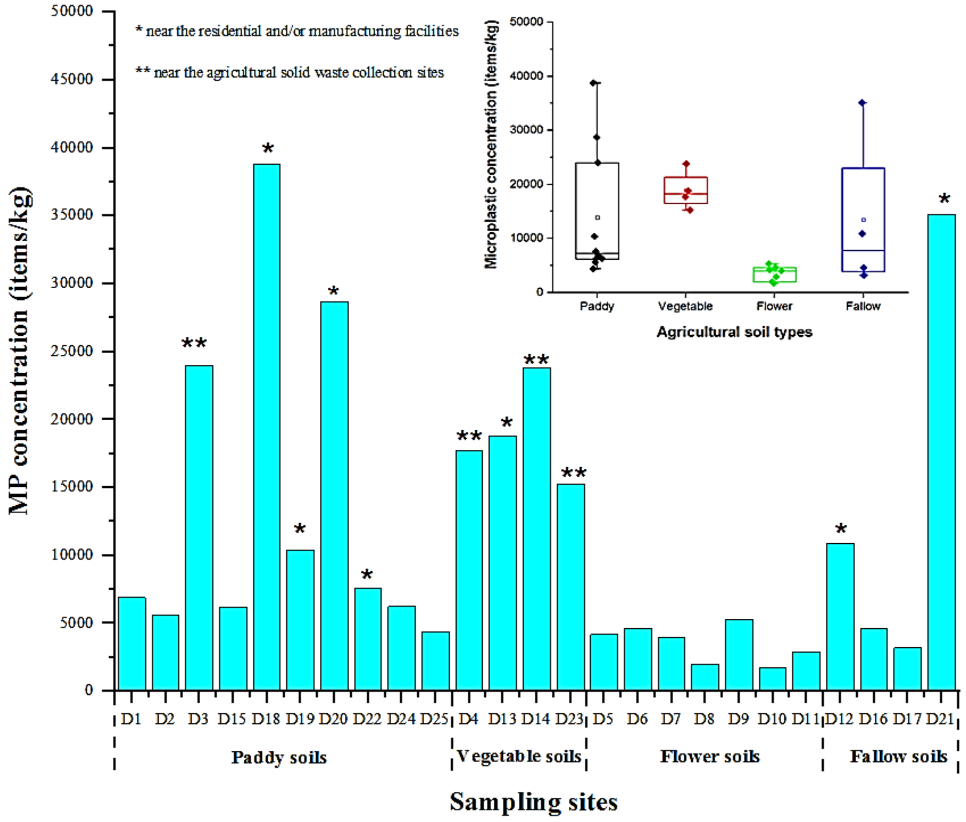

Figure 1. The mean abundance of MPs in agricultural soils (n=3)

At positions D8 and D9, MPs concentrations were detected in the soil samples taken from the areas where lily seedling plants (site D8) and lily flowering plants (site D9) were cultivated. The MP concentration observed at D9 was three times higher than that at D8. The difference in MP concentration between the two soil samples could be attributed to the variations in nutrition and fertilizer application during different growth stages of plants. The use of mulch in agricultural cultivation, soil cultivation, climatic conditions, and applying fertilizers on the same land for many years also led to MP pollution in agricultural soil (Isari et al., 2021). In contrast, some agricultural soil samples (D1, D2, D5, D6, D7, D8, D9, D10, D15, D16, D17, and D25) collected at locations away from residential areas and manufacturing facilities showed lower concentrations of MPs.

Table 3. Microplastic concentration in agricultural soils in the world

Agricultural soil samples	Location	Microplastic concentration (items/kg)	Main polymers	Main size	Main shape	Main color	References
Vegetable fields	China	320-12,560^{a}	PA, PP, PS	< 0.2 mm	Fibers, microbeads, fragments	-	(Chen et al., 2020)
Various	China	240-3,660^{a}	-	< 0.5 mm	Films, fibers,	-	(Lang et al., 2022)
Various	China	1,430-3,410^{a}	PS, PE, PP, HDPE, PVC, PET	0-0.49 mm	Fibers	-	(Ding et al., 2020)
Various	China	4.94-252.70^{a}	PP	0.1-0.5 mm	Fragments	White	(Cao et al., 2021)
Fine herbs and vegetables	Mauritius	320.0±112.2 to 420.0±244.0^{a,b}	PP	< 1 mm	Fibers, fragments	Transparent, black, white, blue, red	(Ragoobur et al., 2021)
Vegetables	China	7,100-42,960^{a}	-	0.05-1 mm	Fibers, fragments, films	-	(Zhang and Liu 2018)
Vegetables	China	22,000-6,900000^{a}	PE, PP, PS, PA, PVC	10-100 µm	Fragments, fibers	-	(Zhou et al., 2019)
Crop	Chile	306±360^{b}	Acrylate,polyurethane, PE, PP, PS	0-2 mm	Fibers, films	-	(Corradini et al., 2021)
Farmland	China	40-714^{a}	PP, PET	< 2 mm	Fibers, fragments	Transparent, black	(Bi et al., 2023)
Rice-paddy	Korean	160±93^{b}	PE, PP, and PET	< 2 mm	Fragments, fibers, sheets		(Kim et al., 2021)
Agricultural land near textile industries	Bangladesh	21,300±1,300^{b}	PS, EVA, latex, HDPE, PVC, ABS, LDPE, PP	-	Fibers, fragments	White	(Hossain et al., 2023)
Farmland	Tunisia	50-880^{a}	PP	< 0.3 mm	Fibers	White/transparent	(Chouchene et al., 2022)
Soils without the addition of sewage sludge	Spain	930±740 to 1100±570^{a,b}	PP, PVC	-	Fragments, fibers, films	-	(van den Berg et al., 2020)
Soils with the addition of sewage sludge	Spain	2,130±950 to 3,060±1680^{a,b}	PP, PVC	-	Fragments, fibers, films	-	(van den Berg et al., 2020)
Various (Vegetable, paddy, flower, and fallow)	Vietnam	1,700-38,800^{a}	PP, PE	< 2 mm	Fibers, fragments	Black, white, purple	This study

Note: Acrylonitrin butadiene styrene (ABS), ethylene-vinyl acetate copolymer (EVA), high-density polyethylene (HDPE), low-density polyethylene (LDPE), polyamide (PA), polyethylene (PE), polyethylene terephthalate (PET), polypropylene (PP), polystyrene (PS), and polyvinyl chloride (PVC); (a): the minimum to the maximum value of MP abundance; (b): the average abundance value of MPs; (a,b): the average range of MP abundances from minimum to maximum

This suggests that the lower concentrations of MPs in agricultural soil at these sites may not be directly influenced by domestic and industrial activities. The study results also suggest that agricultural activities might have caused MP pollution in the soil. Plastic mulching is a widely adopted agricultural practice used globally to protect and increase crop yield and quality (Steinmetz et al., 2016; Feng et al., 2021). These coatings were used as basic polymeric materials, and demand for about 0.7 million tons of coatings per year was reported in 2000 (Ng et al., 2018). Long-term use of plastic materials in the soil can lead to microplastic pollution. In addition, a few studies also reported the reuse of sludge, wastewater, or irrigation water as a source of MP pollution on agricultural land (Horton et al., 2017). Surface water used for agricultural irrigation could come from ditches, ponds, lakes, and rivers. In Vietnam, the MP pollution issue in watersheds was also reported. A MP concentration of 500,000 items/m^3 was found in the Saigon River as it passed through the special urbanization zone of Ho Chi Minh City. It was affected by wastewater discharge from industrial zones, including extensive textile dyeing and garment industries (Lahens et al., 2018). The concentration of MPs in the surface sediment of the main Red River estuary (the Ba Lat) was also reported to be 2,188±1,499 items/kg (Le et al., 2023). Sewage sludge was reported to contain MPs in the range of 1,500-24,000 items/kg and was often recycled for fertilizer on farmland. Therefore, the considerable accumulation of MPs in farm soil might be related to using sludge and wastewater as fertilizers (Mahon et al., 2017; Mintenig et al., 2017; Zhang et al., 2018). Other sources, including flooding, garbage, street runoff, wind, and storms, also appeared as indirect factors that lead to MP pollution in agricultural land (Mahon et al., 2017; Chen et al., 2020; Yu et al., 2021).

3.2. Characteristics of shape, size, and color of MPs in agricultural soil samples

MP characteristics, such as shape, size, and color, were analyzed because they are vital in the soil food web transport processes. In this study, the size and shape of MPs in agricultural soil samples were determined and quantified using a Leica MZ12 microscope. The shape and size distributions were presented in Figs. 2-4. It was easy to see that fibers and fragments were commonly found in all soil samples. Earlier investigations have consistently shown the prevalence of a wide variety of MP fibers in agricultural soil (Ding et al., 2020). Wastewater irrigation and sewage sludge were identified as significant fiber sources on agricultural land (Scheurer and Bigalke, 2018). Wastewater from the washing process could carry many fibers from cloths into the aquatic environment, which is used for irrigation in agriculture (Browne et al., 2011). Fragments are typically present in lower proportions. These fragments could originate from the decomposition of various agricultural plastic waste items, such as agricultural implements, plastic packaging materials, plastic woven bags, and plastic granule bags (Antunes et al., 2013).

The size distribution of MP particles in the agricultural soil samples is shown in Fig. 4a and Fig. 4b. MPs, both in fragments and fibers, were found at the study sites in a range of sizes and areas. The fibers were predominant in the total of microplastic detected at all sites.

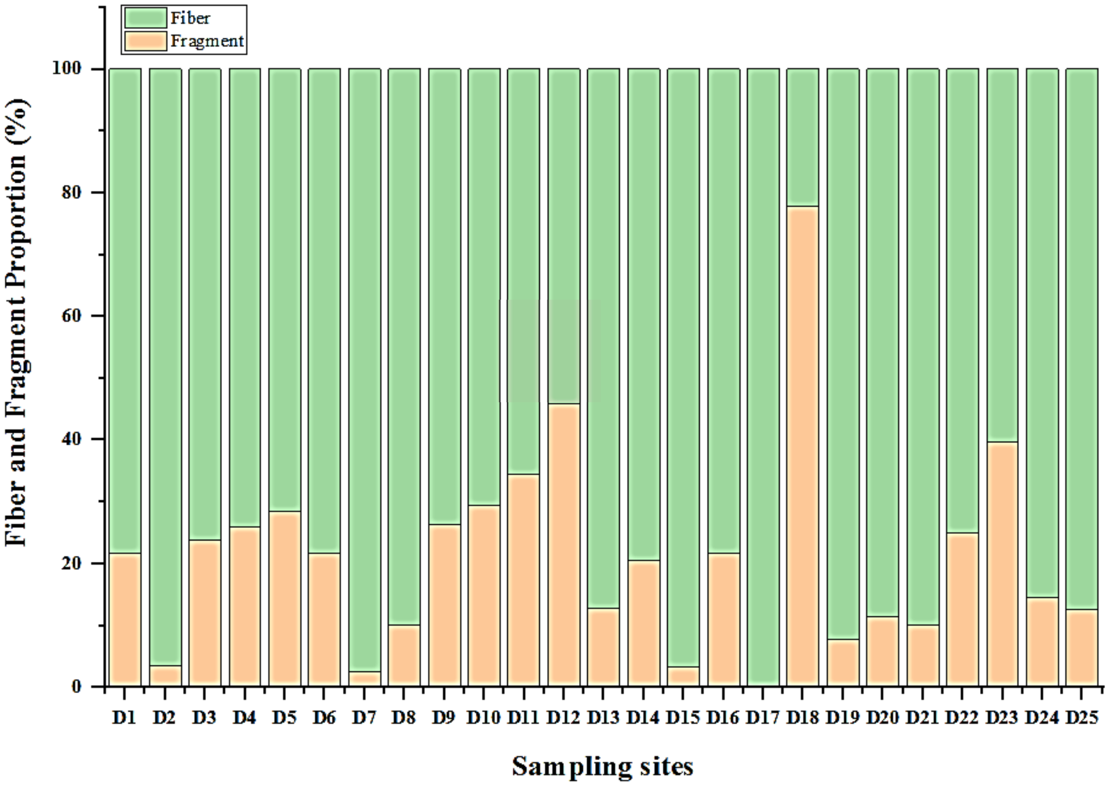

Figure 2. Appearance of microplastic shapes in agricultural soil samples

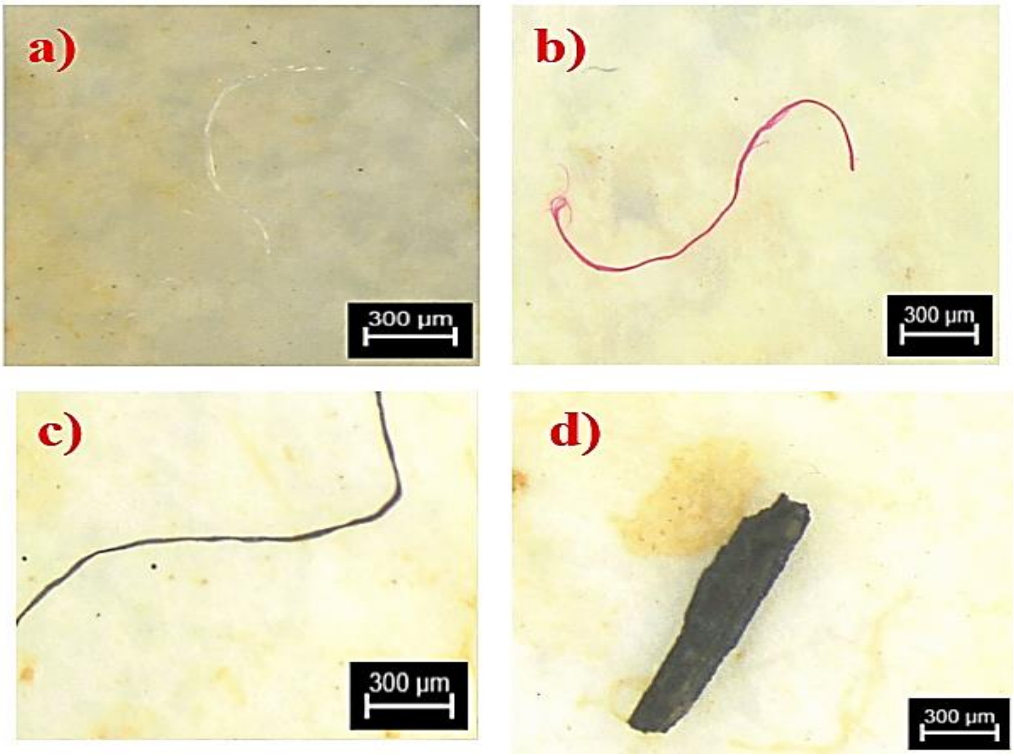

Figure 3. Photographs of MPs under the microscope: fibers (a, b, c), fragment (d)

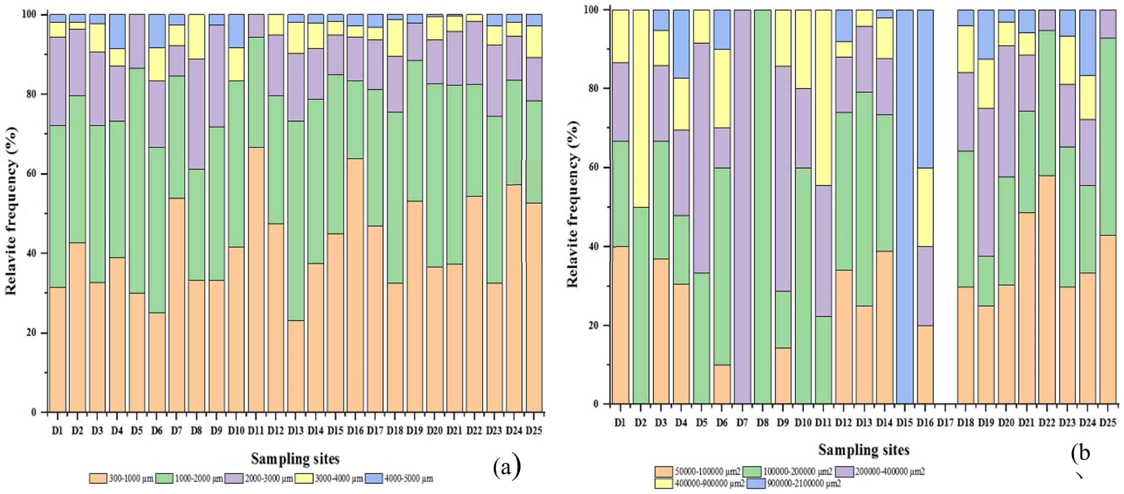

Figure 4. Frequency of microplastic occurrence in fiber (a) and fragment (b) in agricultural soil samples

Fibers of different sizes were classified into < 1,000 µm, 1,000–2,000 µm, 2,000–3,000 µm, 3,000–4,000 µm, and 4,000–5,000 µm, as shown in Fig. 4a. The fibers (< 1,000 µm and 1,000–2,000 µm sizes) accounted for the most significant proportion, with 23.17–66.67% and 19.44–56.67%, respectively. MPs with sizes of 2,000–3,000 µm, 3,000–4,000 µm, and 4,000–5,000 µm accounted for a low proportion in the range of

0–27.78%, 0–11.11%, and 0–8.4%. The average area of MP fragments was 305,381 μm^2 (ranging from 50,170 to 2,034,267 μm^2). The most common areas of fragments were 50,000–100,000 μm^2 and 100,000–200,000 μm^2 (~ 21.87±18.13 % and 31.08±22.60% of total fragments, respectively) (Fig. 4b). Fibers up to 2,000 μm in size were frequently found in the surface water samples and were almost compatible with the current findings (Lahens et al., 2018; Doan et al., 2021). In vegetable farms in the rural area of Wuhan, 70% of MP fibers were < 0.2 mm in size (Chen et al., 2020). The occurrence of tiny MP form could result from physical factors such as UV radiation, high temperature, and chemical abrasion, leading to the gradual fragmentation of larger plastic fragments or persistence of primary MPs (Chai et al., 2020).

Color can give a qualitative indication of the origin of the plastic and the age of the MPs found in the samples (Ragoobur et al., 2021). In this investigation, various colors of MPs were found, including white, black, red, green, blue, yellow, gray, and purple. The predominant colors were white, black, and purple, with 25.29±17.06%, 28.27±17.54%, and 17.67±18.46%, respectively (Fig. 5).

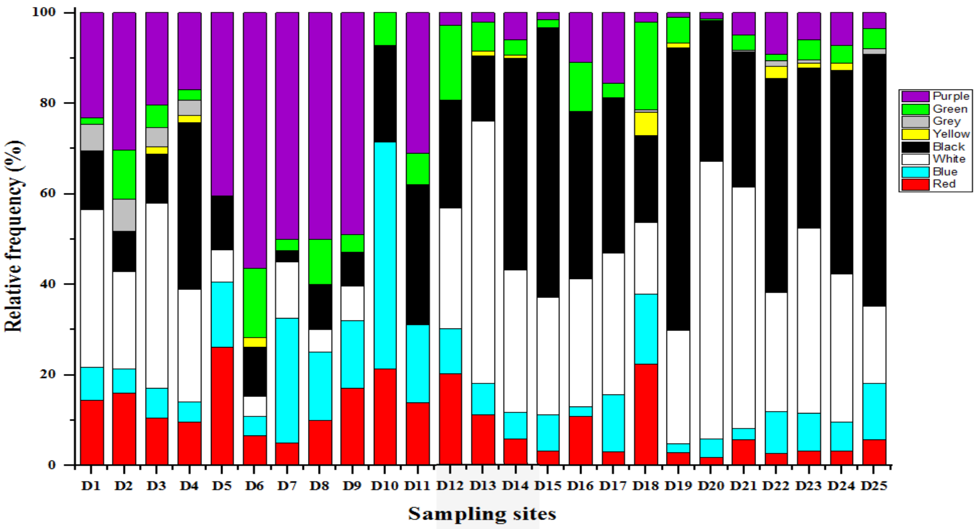

Figure 5. The occurrence of microplastic color in various agricultural soil samples

Our results indicated that colored MP particles accounted for a significant amount. In some prior studies, the color diversity of MPs was also detected in agricultural soil samples (Amrutha and Warrier, 2020; Yu et al., 2021). Some MPs originated from plastic bags, packaging materials, and plastic films, while other colored ones probably came from colored plastic consumables and clothing (Amrutha and Warrier, 2020; Chen et al., 2020). The results showed that industrial and urban waste sources heavily influenced the occurrence of large amounts of colored MPs at the studied sites. In this study, transparent color was not detected. It was found that blue accounted for 10.9±10.03% of the total detected MPs, but some studies also rarely detected them (Liu et al., 2018).

3.3. Polymer composition

The polymer compositions of analyzed MP were polyethylene (PE) and polypropylene (PP), which accounted for 89,4 % of all identified MP, followed by PES (2.39%), PU (1.19%), PVC (0.51%), and acrylic (0.17%). PP and PE are the two most imported and used materials for plastic packaging in Vietnam (Company, 2019). Similar to our findings, PE and PP were previously identified as the most common polymer types in arable soils (Zhou et al., 2019) and surface water (Doan et al., 2021).

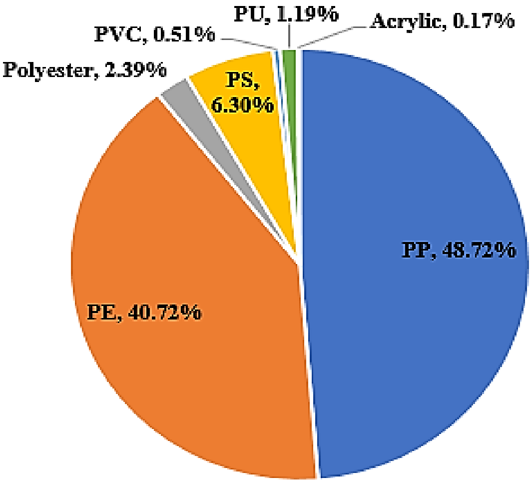

Figure 6. The polymer types of MPs in the agricultural soil samples

3.4. Evaluation of potential ecological risks of MPs in agricultural soil samples

MP in soil can transfer to humans and animals via the terrestrial food chain (Phuong et al., 2018). As a result, it may pose significant risks to organisms and human health (Pan et al., 2021). Customized control measures must therefore be implemented where MP contamination poses a considerable ecological concern. At the moment, the most frequently utilized indicators for MP ecological risk assessment are the pollution load index (PLI), polymer hazard index (PHI), and potential ecological risk index (PERI) (Pan et al., 2021). The MP pollution load at each sampling site was calculated based on PLI (Table 4). Regarding the pollution load index, 72 % soil samples were categorized as hazard level IV. The PLI value for MP determined at D10 site was classified as hazard level II. The PLI is derived from the relationship between the observed MP abundance and the background value, and it is independent of the polymer types of MPs (Ranjani et al., 2021). The abundance of MPs in the agricultural soil could be attributed to the fragmentation of plastic mulch, agrochemical containers, PVC pipes…

The average PLI value discovered in the agricultural soil samples was much higher than those found in the coastal sediments of India (Ranjani et al., 2021), sediment samples in the Buriganga River, Bangladesh (Haque et al., 2023). The difference in PLI values in this inquiry compared with the previous investigation may be due to the amount of background MP contamination C_0. The potential ecological risk of MPs is often used to assess the potential ecological impact of MP abundance and the occurrence of polymers in the environment. In this study, PERI was used to reflect the potential ecological risk of MP in agricultural soil samples, and the calculation results are shown in Table 4. A PERI value of less than 150 (D21 site) was found in 4% of sampling sites. Twelve percent of the sampling sites had a moderate ecological risk level with a mean PERI value of MPs (150–300). D1, D2, D5, D6, D7, D9, D13, D15, D16, D24, and D25 sites with a high ecological risk index (PERI: 300–600), accounted for 40% of the sampling locations. A danger range (600–1,200) and Extreme danger (>1,200) ecological risk index were present at 12% of sampling sites (D12, D19, and D22) and 32% of sampling sites (D3, D4, D13, D14, D18, D20, D21, and D23). The locations were rated for ecological risk from dangerous to highly hazardous mainly due to their proximity to urban residential areas and manufacturing areas, except for D3, D4, D14, and D23 sites, where direct engagement involved agricultural solid waste discharge activities. Therefore, this study suggests that point sources could influence the occurrence of polymers.

Table 4. Evaluation of the Pollution load index (PLI) and Potential ecological risk index (PERI) of MPs in the agricultural soil samples

Sampling sites	Type of agricultural land	PLI	Hazard Level	PERI	Hazard Level
D1	Paddy soil	37.37	IV	595.1	High
D2	Paddy soil	33.67	IV	483	High
D3	Paddy soil	69.70	IV	2,069.9	Extreme danger
D4	Vegetable soil	59.86	IV	1,526.5	Extreme danger
D5	Flower soil	29.16	III	362.2	High
D6	Flower soil	30.52	IV	396.7	High
D7	Flower soil	28.46	III	344.9	High
D8	Flower soil	20.12	III	172.5	Medium
D9	Flower soil	32.75	IV	457.1	High
D10	Flower soil	18.55	II	146.6	Minor
D11	Flower soil	24.23	III	250.1	Medium
D12	Fallow soil	46.97	IV	940.1	Danger
D13	Vegetable soil	61.69	IV	1,621.4	Extreme danger
D14	Vegetable soil	69.41	IV	2,052.6	Extreme danger
D15	Paddy soil	35.43	IV	534.7	High
D16	Fallow soil	30.52	IV	396.7	High
D17	Fallow soil	25.45	III	276	Medium
D18	Paddy soil	88.62	IV	3,346.3	Extreme danger
D19	Paddy soil	45.88	IV	897	Danger
D20	Paddy soil	76.22	IV	2,475.2	Extreme danger
D21	Fallow soil	84.29	IV	3,027.2	Extreme danger
D22	Paddy soil	39.22	IV	655.5	Danger
D23	Vegetable soil	55.56	IV	1,315.2	Extreme danger
D24	Paddy soil	35.57	IV	539.0	High
D25	Paddy soil	29.84	III	379.5	High

They posed a high ecological risk by releasing large amounts of MPs with diverse polymers and highly toxic polymers into agricultural soil. The MP's potential ecological risk level of PERI in river sediments in Shanghai Province, China, and beach sediments in Rayong Province, Thailand, was low (Peng et al., 2018; Prarat and Hongsawat, 2022). However, the PERI values of terrestrial and marine sediments along the Indian coast showed high ecological risk (PERI: 300–600) from combined MP polymers in sediments from Tuticorin (835.7), Kerala coast (597.5), Tamil Nadu coast (476.2), Vembanad Lake (406.7), Goa (346.9), Maharashtra (332.1), and Karnataka (303.2) (Ranjani et al., 2021). Using PERI to assess the potential ecological risks of MPs in soil or sediment samples has been reported by many researchers. Therefore, PERI plays a crucial role in assessing and controlling microplastic pollution in agricultural soil samples.

4. Conclusions

The present study collected agricultural soil samples from 25 sites in Hanoi, Hanam, and Bacninh provinces, Vietnam. The abundance of microplastics in agricultural soils ranged from 1,700 to 38,800 items/kg, with an average of 11,716 ±10,726 items/kg. Microplastic fibers with sizes < 2,000 µm accounted for 75% of total microplastics. The microplastic polymers PP and PE were dominant. Our preliminary risk assessment findings revealed that the medium potential ecological risk index from combined microplastic polymers in agricultural soils was at the danger risk (medium PERI = 1,010±925), and the highest PERI value was 3,346. The PLI values in most agricultural soil samples were greater than 30 (hazard level

IV). More detailed investigations under different agricultural practices should be conducted to better understand the occurrence, distribution, and ecological risks of MPs in agroecosystems. Additionally, more attention should be paid to agricultural soil contaminated by plastic sources such as sewage sludge, fertilization, and plastic-covered farming.

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