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Research Article

Determination of Microplastics as a Pollutant of Agricultural Land

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ABSTRACT

Bosnia and Herzegovina has not yet established adequate plastic waste management systems, which contributes to the increasing presence of microplastics in soil. Microplastics in soil may affect its physical properties, reduce water retention capacity, and negatively influence plant growth by inducing oxidative stress and reducing seed germination. This study investigates the presence of microplastics in different types of agricultural land (pasture, garden, arable land, mountain soil, and greenhouse soil) within the Tuzla Canton. The results confirmed the presence of microplastics in all analyzed samples. Land use, environmental conditions, and past anthropogenic activities at the sampling sites influenced the occurrence and distribution of microplastics. Microplastics were identified through microscopic analysis based on particle number, morphology, and color. The detected concentrations ranged from 40 to 80 particles/kg. Although microplastics were present in all samples, no significant adverse effects on agricultural production or the health of humans and animals were observed within the scope of this study. The findings highlight the need for further research and improved waste management practices to better understand long-term environmental impacts.

Keywords: Bosnia and Herzegovina, agricultural production, plastic waste, microplastics, soil fertility, microscopic analysis.

INTRODUCTION

Microplastic pollution has been identified as the second most serious scientific problem in the field of environmental protection. According to relevant research, the prevalence of microplastics on land is 4 to 23 times higher than in the oceans. As with other harmful substances, soil is the ultimate sink for pollution. The problem of soil contamination with microplastics is very serious, and one of the most significant risks is the introduction of microplastics into the human body through food [1, 2].

The presence of microplastics in soil reduces soil quality, and their distribution, especially in heavily polluted areas (e.g., use of treated wastewater and mulching films in agricultural production), poses a significant threat to the ecosystem. The distribution of microplastics in soil depends on biocenosis, soil composition and porosity, pore size, and the presence of cracks, as well as agronomic practices such as tillage (plowing) and harvesting technologies [3-5].

Soil processes that influence potential sinks and the effects of microplastics are related to soil cracking and wet–dry cycles. The formation of cracks and fissures during dry conditions is common in agricultural soils, and these cracks represent pathways for plastic particles to reach deeper soil layers [6,7].

Examining the adsorption affinity of different types of microplastics to pollutants present in soils is of vital importance for comprehensive assessment and risk management. In addition, understanding the structure of microplastics and the mechanisms of adsorption of organic pollutants is necessary to clarify the role of microplastics as vectors for the transport of contaminants in the soil medium [8,9].

The presence of microplastics in soil also affects the food chain of animals such as hamsters, moles, earthworms, and roundworms. Microplastics can attach to organisms, affecting their movement, transformation, and degradation in soil, and may lead to physical and physiological disorders, reduced plant growth and development, oxidative stress, and reproductive complications [10,11].

The most commonly detected types of microplastics in ecosystems are polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS), polyurethane (PUR), and polyethylene terephthalate (PET). Various studies have indicated the possibility of adsorption of different contaminants on microplastics, such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), dioxins, polybrominated diphenyl ethers (PBDEs), heavy metals, hydrophilic organic compounds, and pharmaceutical active compounds [12-14].

Current research methods for microplastics are based on the isolation and characterization of microplastic particles in order to assess their impact on soils. The aim of this study is to determine the qualitative and quantitative presence of microplastics in agricultural soils of different quality and land-use types.

MATERIALS AND METHODS

Materials

The research area included the Tuzla Canton, encompassing several specific locations: the City of Lukavac (Panjik local community, sample 1 – reference sample representing unpolluted soil), the City of Tuzla (Solina local community, where sample 2 was collected from grassland/pasture, sample 3 from arable land, and sample 4 from a household garden), and the Municipality of Čelić (Brnjik local community, sample 5 – soil from a greenhouse used for controlled agricultural production).

Soil sampling was conducted to assess the presence and distribution of microplastics across different land-use types, including natural or minimally impacted soil (reference site), pasture (grassland used for grazing), arable land (actively cultivated field), garden soil (intensively managed small-scale cultivation), and greenhouse soil (protected cultivation system). In addition, a blank sample was prepared to identify potential microplastic contamination originating from laboratory procedures, particularly during salt-based density separation and subsequent treatment with H_2O_2.

The materials and equipment used in the analysis included a metal shovel for soil sampling; glass sample containers (ten per sample) and aluminum foil for sample storage; a 5 mm metal sieve and a porcelain mortar with pestle for sample preparation; and an analytical balance for mass determination.

Glass microfiber filters (GF/F or GF/C), glass beakers, and stirring rods were used during sample processing. A glass density separator with a sodium chloride (NaCl) solution and 400 mL of filtered distilled water per sample was applied for density separation. Organic matter was removed using a water bath and 30% hydrogen peroxide (H_2O_2).

Filtration was carried out using membrane filter paper (Millipore S-pack, 47 mm) and quantitative filter paper (12–15 µm), with the aid of a vacuum pump and metal tweezers. Microscopic analysis was performed using a Leica DM 2500P microscope and an Olympus SZ61 stereomicroscope (4×/0.10 and 10×/20 eyepieces), while image acquisition and processing were conducted using AmScope and CorelDRAW software.

Methods

The determination of microplastics in soil samples was performed using the methodology described by Gundogdu. The procedure consisted of several sequential steps, including sampling, removal of coarse aggregates, dispersion of soil aggregates, density separation, digestion of organic matter, filtration, and visual identification of microplastics.

It should be noted that polymer identification was based on visual characteristics observed during microscopic analysis; therefore, the results should be considered tentative due to the absence of spectroscopic confirmation (e.g., FTIR or Raman analysis).

Experimental procedure

The area of the sampling location was 20 × 50 m, except for the greenhouse sample (sample 5), where the size of the examined area was 5 × 20 m. Within each sampling site, ten microlocations (subsampling points) were defined and distributed diagonally across the plot. Soil samples were collected from each microlocation at a depth of 5 cm using a metal shovel and stored in glass containers. At each location, ten subsamples were collected, corresponding to ten microlocations, and then combined into a composite sample. The composite samples were homogenized, crushed, and sieved through a 5 mm metal sieve.

The prepared soil samples were dried at room temperature in a closed room on aluminum foil for five days. From each homogenized sample (1 kg), a representative subsample of 250 g was taken and placed in glass beakers for further analysis.

A total of 400 mL of filtered distilled water was added to all pre-weighed samples (a GF/F or GF/C grade glass microfiber filter was used for water filtration). All samples were thoroughly mixed with a glass rod until homogenized and left overnight to allow the liquid phase to separate from the soil. Density separation was performed using a prepared NaCl solution (1.2 g/cm³), which was added to each sample to a level 3 cm above the sample and then mixed thoroughly. The availability, low cost, and environmentally friendly nature of density separation media, such as distilled water and salt, have contributed to their frequent use in microplastics testing.

The prepared NaCl solution was also treated as a blank sample to identify potential contamination originating from the salt or subsequent treatment with H_2O_2. All samples were transferred to a glass density separator and left for 24 hours to allow separation of the aqueous phase (supernatant) from the solid fraction.

After settling, the supernatant was carefully decanted, and the walls of the separator were rinsed with distilled water to ensure complete transfer. The collected supernatant was transferred into clean glass containers.

Subsequently, 250 mL of filtered 30% hydrogen peroxide (H_2O_2) was added to each sample and the blank sample. The samples were placed in a water bath at 60°C and stirred until digestion of organic matter was complete, as indicated by visual clarification of the solution. After cooling, the samples were left overnight to ensure complete oxidation of residual organic matter.

Following digestion, the samples were filtered to separate the liquid and solid phases. A representative volume of 100 mL from each sample and the blank was then filtered through membrane filter paper (Millipore S-pack, 47 mm) using a vacuum pump, followed by filtration through quantitative filter paper (12–15 µm pore size).

After filtration, the filters were carefully removed, placed in closed glass Petri dishes, labeled accordingly, and left to dry at room temperature overnight prior to analysis.

RESULTS AND DISCUSSION

The microscopic analysis revealed a diverse range of microplastic morphologies, including regular, partially regular, and irregular geometric shapes, as well as reticulate and needle-like structures. These particles exhibited a variety of colors, such as blue, brown, purple, and gray. The presence of these varied forms and colors confirms that the sampled soil has been subjected to multiple sources of plastic contamination, leading to *in situ* degradation and the subsequent accumulation of microplastics within the soil matrix.

Quantitative and Morphological Analysis

The highest concentration of MPs was recorded in The highest concentration of MPs was recorded in Sample 4 (garden) with 80 particles/kg and Sample 2 (pasture) with 75 particles/kg (Figure 1).

Sample 4 (Figure 2) exhibited the highest morphological diversity, containing threadlike, anhedral, and subhedral particles, as well as unique round shapes. This suggests a complex accumulation of MPs from various sources, including household waste and degraded plastic packaging.

Threadlike particles (fibers) were the dominant morphology across all sites, particularly prominent in Sample 3 (field), where 11 out of 65 identified particles were fibers (Figure 3). These fibers, often blue or purple, are typically associated with atmospheric deposition or the degradation of synthetic textiles.

Based on visual characteristics and common agricultural practices in the Tuzla Canton, several polymer types were tentatively identified.

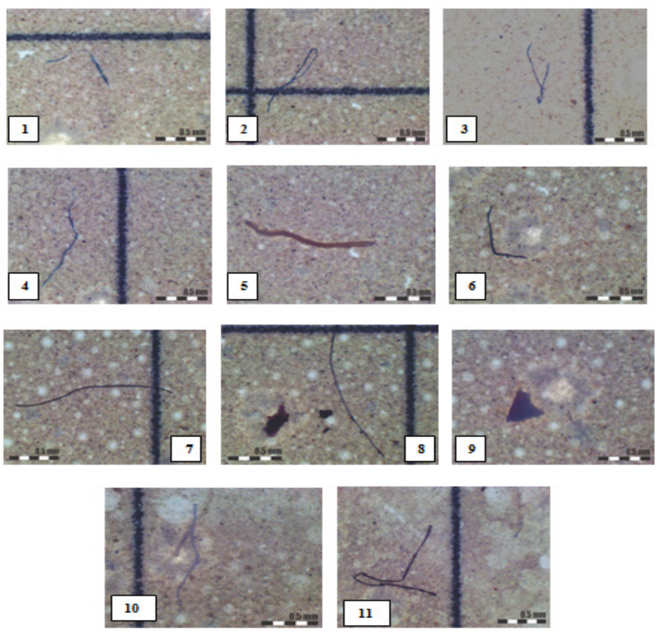

Figure 1: Microscopic analysis of sample 2.

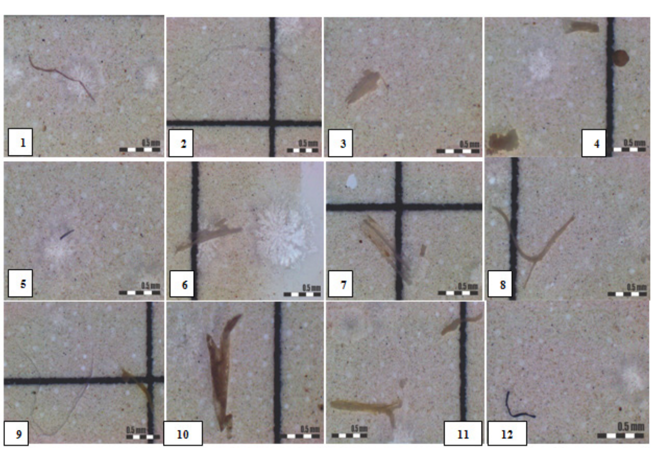

Figure 2: Microscopic analysis of sample 4

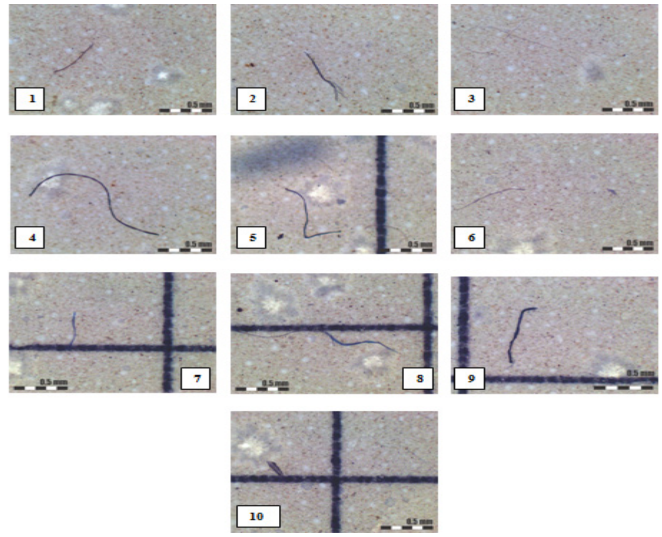

Figure 3: Microscopic analysis of sample 3

MPs was identified primarily in Sample 5 (greenhouse) and Sample 4 (garden). The presence of pronounced black particles in the greenhouse sample (Figure 4) strongly correlates with the use of mulching films.

MPs contamination was observed in Sample 0 (blank sample), which contained 55 particles/kg, (Figure 5). The blank sample results indicate possible laboratory contamination during the MPs research. Correction of the results was not performed because some samples, such as Sample 1, would have a reduced number of identified MPs particles, but it is presented and discussed on the above topic in the discussion and conclusions.

The detection of 40 particles/kg even in the Mount Ozren area Sample 1 (Figure 6) indicates that microplastic pollution is not limited to industrial or urban zones. Transport mechanisms such as wind and water runoff (floods) likely play a significant role in distributing these pollutants to higher altitudes and relatively remote areas.

Furthermore, the relatively recent introduction of intensive greenhouse production in parts of the Tuzla Canton (e.g., Čelić) suggests that many plastic materials have not yet reached their full degradation stage. Consequently, although current evidence does not

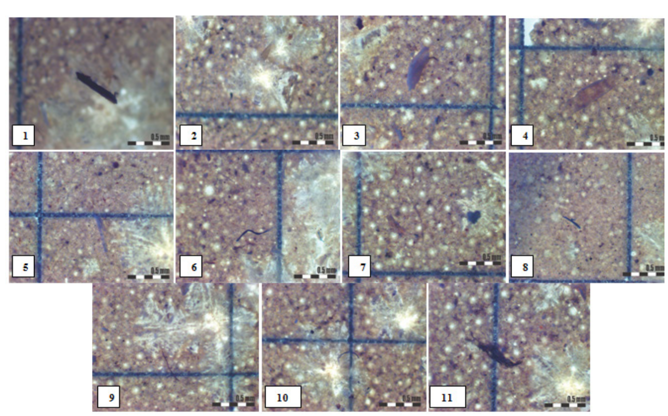

Figure 4: Microscopic analysis of sample 5

Table 1: Overview of the microscopic analysis of the samples

Sample	*Number of particles (n/kg)*	*Morphology*	*Color*
0	55	Threadlike x 7, Anhedral x 3, Subhedral	Blue, Brown
1	40	Threadlike x 7, Anhedral	Blue, Purple
2	75	Threadlike x 12, Anhedral x 2, Subhedral	Blue, Brown, Purple, Grey
3	65	Threadlike x 11, Anhedral, Subhedral	Blue, Purple
4	80	Threadlike x 5, Anhedral x 7, Subhedral x 3, Round shape	Blue, Brown
5	65	Threadlike x 4 , Anhedral x 3, Subhedral x 4, Needlest, Prismatic elongated	Blue, Brown

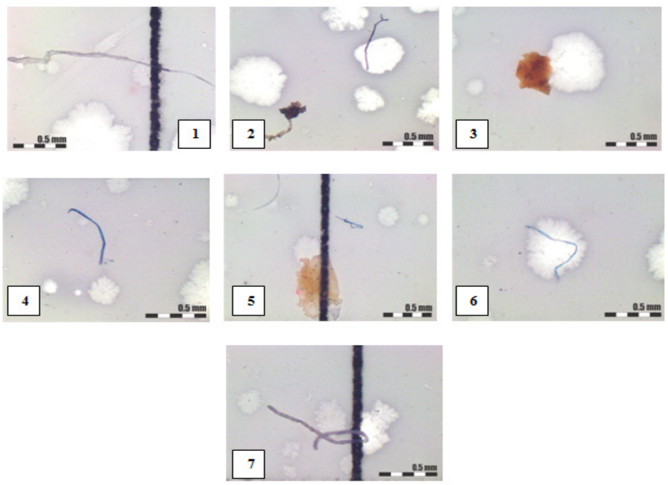

Figure 5: Microscopic analysis of sample 0. (blank sample)

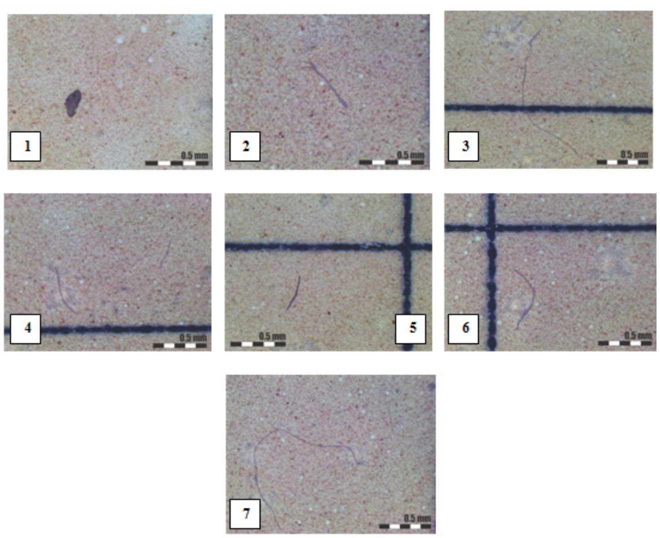

Figure 6: Microscopic analysis of sample 1

indicate direct negative impacts on agricultural yield or human health, the continuous accumulation of MP fragments may pose long-term risks to soil properties and the terrestrial food chain.

The microscopic analysis confirmed the presence of microplastics (MPs) in all investigated soil samples from the Tuzla Canton, with concentrations ranging from 40 to 80 particles/kg (Table 1). While these values are relatively low compared to global hotspots, the diversity in morphology and color provides important insight into the sources of pollution in the region.

The detected concentrations of 40 to 80 particles/kg in the Tuzla Canton are comparable to those reported in certain agricultural soils, such as suburban farmland areas of Shanghai [15], where similar values were observed depending on soil depth. However, significantly higher concentrations have been reported in regions with long-term intensive agricultural practices, particularly where plastic mulching is widely used.

The relatively low values observed in this study can be attributed to several factors. Firstly, the use of plastic materials in agriculture in the Tuzla Canton is relatively recent. Secondly, lower population density in rural areas, such as Mount Ozren, likely limits the input of secondary microplastics from household waste.

The microscopic analysis (Table 1) revealed a clear dominance of fibrous particles across all sites, which is consistent with previous studies highlighting atmospheric deposition as an important pathway for microplastic contamination [16].

The highest number of microplastic particles was observed in continuously cultivated soils, suggesting that agricultural practices contribute to their accumulation. In addition, microplastics can migrate into deeper soil layers under the influence of tillage, precipitation, and biological activity [11], while physical changes in soil properties associated with plastic contamination have also been reported [17].

Black particles are most likely associated with mulching films, while transparent particles may originate from cellulose contamination that was formed during filtration. External factors such as wind, floods, landslides, and agricultural machinery further contribute to the distribution of microplastics.

Although microplastics were detected in all samples, the concentrations remain relatively low, and no significant negative effects on agricultural products or on human and animal health were observed. However, their presence is expected due to environmental exposure and agricultural activities.

The identification of polyethylene fragments associated with mulching films in Sample 5 is consistent with findings from agricultural soils in Germany [18], where macroplastic residues were identified as a major source of secondary microplastics. Although current levels are not critical, the presence of MPs indicates the need for improved plastic waste management to prevent future accumulation.

CONCLUSION

The conducted research confirmed the presence of microplastics in all analyzed agricultural soil samples from the Tuzla Canton, Bosnia and Herzegovina, indicating that microplastic contamination is already a detectable component of terrestrial ecosystems in this region. However, the determined concentrations (40–80 particles/kg) are relatively low compared to values reported in highly industrialized or intensively cultivated areas worldwide.

Microscopic characterization based on particle number, morphology, color, and size enabled the tentative identification of dominant microplastic types. The presence of black particles suggests the contribution of agricultural practices, particularly the use of mulching films, while fibrous particles indicate atmospheric deposition. At the same time, transparent particles point to possible cellulose contamination originating from filter materials, highlighting the importance of blank sample correction.

The occurrence of microplastics across all sampling sites, including less anthropogenically impacted areas, suggests that their distribution is influenced not only by local agricultural activities but also by environmental factors such as wind, floods, and soil disturbance.

Although no significant negative effects on agricultural productivity or on the health of humans and animals were observed, the continuous accumulation of microplastics may pose long-term environmental risks.

Therefore, continuous monitoring, improved waste management practices, and further research are necessary to better understand the long-term behavior and impacts of microplastics in soil systems.

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CONFLICT OF INTEREST

The authors do not have any conflicts of interest.

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