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The Impact of Single-Use Mask Waste on the Quality of Loamy Soil

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ABSTRACT

The COVID-19 outbreak has significantly raised the amount of single-use mask waste in Indonesia. This research intends to assess the effect of single-use mask waste on the quality of loamy soil. The investigation involved constructing a prototype using a 28–cm high column of 19 cm of loamy soil. The study utilized single-use masks in the soil, in which Chili plants were grown on the soil surface. Clean water was employed for the leaching process over 45 days. Soil samples from control, R1, R2, and R3 reactors were analyzed in the laboratory using X-ray fluorescence (XRF) testing and microplastic identification in groundwater. The research findings reveal a notable decline in macro and micronutrients, namely a 1.22% decrease in silicon minerals caused by microplastics interfering with plant metabolic processes. The increase in microplastics caused higher microorganism mortality, leading to a 10.18% decrease in organic carbon content and a 1.47% reduction in soil porosity. Microplastics were discovered in the loamy soil of an average size of 0.3 ± 1.34 mm. Changes in nutrient concentrations and physical properties of the soil indicate that introducing microplastics into loamy soil through mask waste can alter soil characteristics. Additional research is required to investigate the disposal of single-use mask waste due to the ongoing high utilization of disposable masks as personal safety equipment.

Keywords: single-use mask, microplastics, loamy soil, soil characteristics.

INTRODUCTION

The COVID-19 pandemic has increased public awareness regarding the usage of single-use masks for personal protection, leading to a surge in demand for disposable masks. To prevent and control COVID-19 in workplaces, offices, and industries, the Indonesian Ministry of Health Regulation No. HK.01/07/MENKES/328/2020 mandated to use masks when leaving home. Data shows increased medical waste, specifically disposable masks, during the pandemic. The WHO reports that single-use mask waste has risen worldwide to almost 129 billion each month (Oginni, 2022). Approximately 1.6 billion single-use masks, equivalent to 5,500 tons of plastic waste, have reportedly sunk into the oceans. During the pandemic, Indonesia was the second-highest contributor to medical waste production, producing an average of 212 tons per day (Rinaldi and Anjari, 2021). On the other hand, garbage management in Indonesia remains insufficient, with around 60% of garbage not being managed by local authorities and only approximately 25% of waste types being properly collected and handled (Qodriyatun, 2014). Single-use masks are mainly composed of polypropylene fibers with a non-woven structure resembling plastic (Mentari et al., 2022). Polypropylene is a thermoplastic polymer characterized by fine fibers and high density (Setiorini, 2020). These fibers create a dense network capable of capturing micro-sized particles (Kusumaningrum et al., 2017). Polypropylene is hydrophobic, so it does not absorb water. Therefore, disposable polypropylene masks are effective in trapping water droplets, particularly those carrying pathogens or contaminants. Single-use masks are composed of three layers: an outside layer of water-resistant and light-permeable non-woven polypropylene, a soft inner layer of white non-woven cotton, and a middle layer of white polypropylene fiber (melt-blown) that serves as a bacterial and particle filter (Khoironi et al., 2023). Despite the ability of soil to filter pollutants, microplastics can still impact soil characteristics and quality (Mentari et al., 2022). Microplastics degraded by and released from disposable masks can diminish soil quality (Aragaw, 2020), groundwater, and growing plants, affecting human health (Trevisan et al., 2022). Numerous research has investigated the impact of microplastics on soil quality, groundwater, and soil microorganisms and the role of soil characteristics in plastic degradation. Xu's (2020) review indicates that microplastics have a substantial role in soil contamination and the build-up of toxic substances in soil. De Souza Machado et al. (2019) researched the impact of plastic pollution on soil properties and plants by utilizing soil as a growth medium. Their findings showed that microplastics altered the soil's characteristics and decreased the growth of onion plants, affecting the number of leaves and bulb biomass. Lozano and Rillig (2020) showed that plastic fibers affect soil water retention and absorption, reducing soil bulk density and root mass. Zhou et al. (2020) studied the ecological and environmental impact of microplastic pollution in soil and discovered that polypropylene microplastics raised soil bulk density by 2%. Dissanayake et al. (2021) studied microplastics in South Korea and found that single-use masks were the primary source, adding more than 1,381 million microplastic fibers daily. These various findings on the impact of microplastic pollution in soil serve as references for further research. This research investigates the impact of burying single-use mask waste in soil on soil quality and capillary water, assuming the waste degrades into microplastics. Moreover, the effect on plants will indicate altered soil quality from contamination by single-use mask waste.

METHOD

Preparation sample

The study started by constructing four identical reactors, as illustrated in Figure 1. Loamy soil sample (24 kg) was equally distributed across four reactors. The filling process commenced by putting a wire mesh filter and then adding the appropriate amount of gravel and sand. The loamy soil was combined with a tiny quantity of sand and placed into each reactor until it reached a height of 10 cm. Subsequently, 16 single-use medical masks (Surgical Face Mask 3-ply earloop, Sensi brand, green color, item code: CME-gbs175-020-A, product code: SM-3EP-20-G) were placed into reactors R1, R2, and R3. After covering it with a layer of loamy soil, the height reached 19 cm. A control reactor was the reference point to study the impact of masks on plants, soil, and capillary water. Chili plants were grown in each reactor to indicate changes in soil quality from the presence of disposable masks. NPK fertilizer, which contains Nitrogen, Phosphate, and Potassium was added to all reactors as fertilizer. Each reactor was initially watered with 1000 ml consistently at regular intervals for 45 consecutive days

Analysis

The loamy soil samples were examined with the XRF WDXRF Rigaku Supermini 200 instrument and a visible spectrophotometer (Thomas et al., 2020; Möller et al., 2020). The initial steps were of measuring the loamy soil and placing it into reaction tubes. Reagents were added, and the volume was compressed with deionized water. The reaction

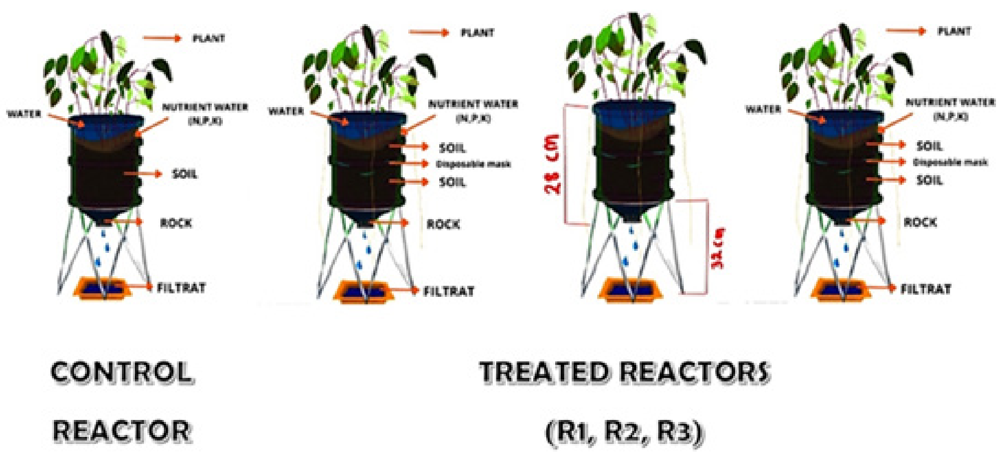

Figure 1. Set up of control and treated reactors

tubes were left undisturbed for 24 hours. The glucose standard series was treated in the same method, with a color change to green, indicating a successful reaction. Subsequently, the absorbance was determined. The first stage in analyzing and identifying microplastics in the soil involved drying the soil and grinding it to the necessary fineness to remove clumps. In NaCl solution, 3 grams of dirt were dissolved at a concentration of 60 g per 100 ml and centrifuged at 2000 rpm for 15 minutes. During this stage, suspended particles accumulate on the surface of the solution. The suspended material was filtered through filter paper (Figure 2a), and the resulting solution was diluted in either 70% ethanol or 30% hydrogen peroxide (H_2O_2) to neutralize or remove undesired components. The subsequent stage was re-filtering the material and allowing it to dry on filter paper, as shown in Figure 2 (b, c). The drying procedure was performed utilizing a vacuum oven (Figure 2d). The dried filter paper with the sample was examined using a Stereo Zoom NSZ 606 microscope with an Optilab Advance Plus camera for identification.

RESULT AND DISCUSSION

The impact of disposable mask contamination on the soil nutrients

The extensive utilization of single-use face masks during and after the COVID-19 pandemic caused concerns regarding its environmental effects on soil quality and nutrient content. Disposable face masks can contaminate soil nutrients, causing detrimental effects (Kwak and An, 2021). The components found in masks, including synthetic fibers, rubber, metals, and chemicals, can impact soil structure, texture, and air circulation, which may hinder the growth of soil microorganisms. Sajjad et al. (2022) found that contamination from disposable face masks can disturb the natural nutrient cycle in soil, altering nutrient availability and accessibility for plants. Consequently, plant root nutrient uptake may be impeded, resulting in nutritional shortages impacting plant growth (Ramadhani, 2022). Disposable face masks are produced using additional chemicals, such as lead and cadmium. Their improper disposal might accumulate heavy metals in the soil, which may negatively impact soil composition, hinder soil microorganism activity, and pollute groundwater (Alengebawy et al., 2021). Disposable face masks composed of polypropylene may release microplastics into the environment as they break down in soil. Mammo et al. (2020) suggest that microplastics can influence soil microorganisms and cause detrimental consequences in the food chain. Analyzing the physical parameters of loamy soil holds significance, as it provides a fundamental understanding of the soil's behavior regulation mechanisms, energy exchange interactions, and water and material cycling capabilities. Chemical parameters in loamy soil, including organic matter and macronutrients (P, K, S, Ca, and Mg), play roles in plant respiration and photosynthesis (Zewide and Reta,

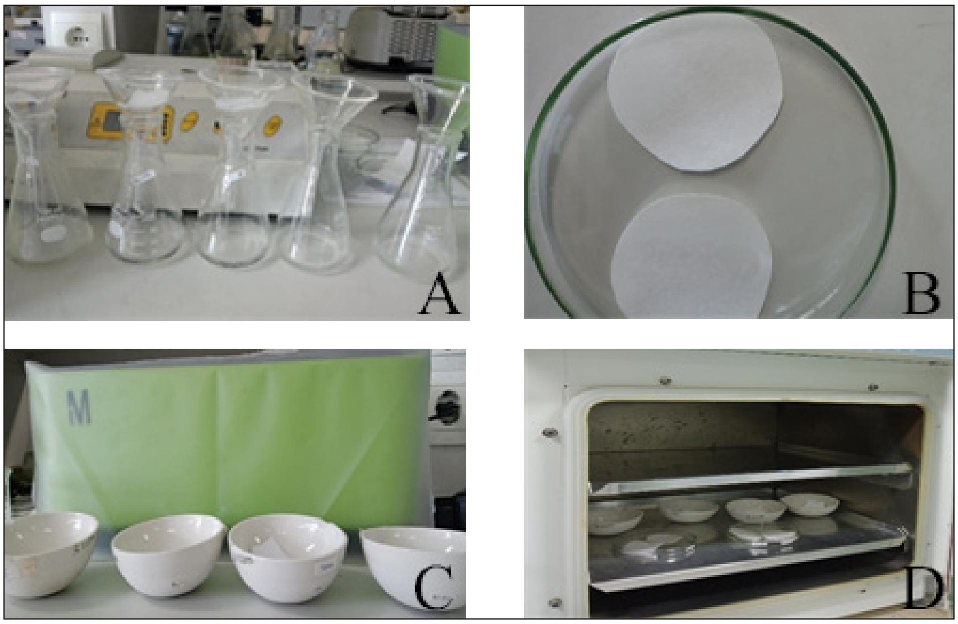

Figure 2. Preparation sample for analysis: (a). filtration, (b) filter paper (c) re-filtering, (d) drying

2021). Micronutrients also have a crucial role in the formation of enzymes and hormones in plants (Sharifi, 2013). The interaction between micro and macronutrients in plants is discussed in the research by Kumar et al. (2021). Sufficient micronutrients can influence the uptake and utilization of macronutrients by plants. Conversely, micronutrient deficiencies can disrupt efficient macronutrient utilization by plants. Table 1 shows several essential micro and macronutrients in loamy soi

Table 1 displays plants' macronutrients (P, K, S, Ca, and Mg) and micronutrients. Only a small number of micronutrients are necessary to prevent adverse effects. Micronutrient deficits in plants, however, limited in amount, can result in plant deficiencies, which may manifest as alterations in leaf color and texture, stunted growth, and irregularities in flower and fruit development (Zewide and Sherefu, 2021). In loamy soil, the macronutrients calcium (Ca) and magnesium (Mg) fell by 0.24% and 0.07%, respectively, when comparing the control soil to the treated soil. The micronutrient silicon (Si) decreased by 1.22%, while aluminum (Al) decreased by 0.7%. Nutrients reduce when microplastics accumulate in the soil, disrupting soil structure and decreasing drainage and soil aeration. This may lead to an overabundance of water and a lack of oxygen in the plant's root zone, inhibiting root growth and disrupting essential biological processes necessary for nutrient uptake (Zhang et al., 2023). Microplastics can impact soil pH in complex ways (Zhao, 2021). When soil pH decreases, minerals such as Al, Ca, Mg, and Si may become more soluble and leak out of the soil via leaching.

The impact of disposable mask contamination on the soil physical characteristics

Disposable masks include chemical components such as dyes, preservatives, and other additives. Disposing of these masks in the soil might leach chemical substances, contaminating the ecosystem. The contamination can disturb

Table 1. Assessment for the change of mineral content in loam soil

Sample	Elements	Concentration		
		Composition (%)		
		Blank	Control	Treated
Loamy soil	Mg	0.2799	0.2291	0.1552
	Al	6.5664	6.9904	6.2966
	Si	10.2644	10.5040	9.2803
	P	0.1299	0.2095	0.1649
	S	0.1738	0.1108	0.0841
	Cl	0.0976	unidentified	0.0140
	K	0.7268	0.5015	0.4520
	Ca	1.9070	2.0622	1.8157
	Ti	0.4819	0.5875	0.4665
	V	0.0197	unidentified	0.0204
	Mn	0.1435	0.1397	0.1204
	Fe	5.4443	5.2124	5.0845
	Cu	0.0133	0.0138	0.0139
	Zn	0.0170	0.0100	0.0119
	Sr	0.0172	0.0170	0.0161
	Zr	0.0090	0.0092	0.0109
	Ag	0.0452	unidentified	unidentified
	Cr	0.0149	0.0112	0.0125
	Ni	0.0034	0.0043	0.0036
	As	0.0023	unidentified	0.0004
	Cd	0.0102	0.00078	0.0057
	Pb	unidentified	0.0045	0.0014
	Hg	0.0038	0.0040	0.0043

the equilibrium of the soil ecosystem and potentially harm microbes and other soil creatures (Li et al., 2023). Improperly managed accumulation of single-use masks can disturb soil structure. As these masks build up, they can block air and water movement in the soil, hinder water flow, and decrease the availability of nutrients for plants (Li et al., 2022). Alterations in soil structure density can impact soil fertility. If single-use masks are disposed of near water sources such as rivers or wells, they may be transported by rainwater and pollute groundwater (Knicker and Velasco-Molina, 2022; Gurnita et al., 2022). Chemicals and microplastics from masks can dissolve in water and contaminate drinking water sources, affecting the quality of water for humans, aquatic life, soil, plants, and soil microorganisms (Zhao et al., 2022; Selvaranjan et al., 2021). Alterations in soil characteristics will affect soil quality and functionality in ecosystems (Gregory et al., 2015). A thorough examination is required, as water flow through the soil is greatly influenced by its characteristics. The Food and Agriculture Organization (FAO) states that soil serves as a source of various contaminants. Groundwater source quality is determined by the movement of the soil and the distribution of pollutants. Therefore, soil function and features are vital in influencing how pollutants move towards groundwater sources (Cheng, 2021). The following are the findings about the physical attributes of loamy soil following exposure to microplastics from disposable masks.

Soil water content

Water content is the proportion of water volume compared to the total soil volume at a specific location or depth. Water content level in the soil is essential, as it impacts plant growth, water infiltration, groundwater storage, and soil chemical and biological activities (Irmak, 2019).

Table 2 displayed no significant difference in water content between the control soil and treated soil. However, there was a significant 6.09% increase between the blank and control soil samples. Single-use masks breaking down into microplastics might trap water on the surface or between particles of loamy soil. Hydrophobic microplastics can impede water from entering the soil or interfere with water flow in loamy soil (Jing et al., 2023; Wang et al., 2023). Consequently, the polluted, loamy soil layer may trap soil watering. The water content in loamy soil may rise due to contamination by single-use masks that have degraded into microplastics (Machado et al., 2019)

Soil specific weight

The specific weight of loamy soil is the mass density of the soil per unit volume, which accounts for the combined weight of solid soil particles and the water in the soil pores. In the analysis of microplastic pollutants in loamy soil, the specific weight can offer information about the soil's physical density and pore structure. This information is significant because microplastics can impact a soil's physical and chemical characteristics and the interactions between microplastics, soil, and other environmental components (Asatyas, 2021). The specific weight of the loamy soil decreased from 1.55 g/cm³ to 1.51 g/cm³ in the treatment reactor after 45 days, showing a drop of 0.04 g/cm³ compared to the control reactor, as presented in Table 3. The decline is caused by the breakdown of disposable masks into microplastics, which alters the structure of the loamy soil. Microplastics can infiltrate soil pores, displacing soil particles and diminishing available space. Sajjad et al. (2022) stated that this action can reduce the density or specific weight of loamy soil. Furthermore, Microplastics can change the compressibility properties of loamy soil because they are more flexible and elastic than soil particles (de Souza Machado et al., 2018). This can alter soil compression behavior, consequently impacting specific weight (Jing et al., 2023). The changes in soil characteristics can also impact the loamy soil's water retention capacity. Suppose microplastic pollution hinders the soil's capacity to drain water adequately. In that case, it can raise soil moisture levels since water is less dense than dirt.

Table 2. Water content of loamy soil

Parameter	Sample	%
Water content	blank	39.21
	control	45.30
	treated	45.31

Table 3. Specific weight of loamy soil

Parameter	Sample	gram/cm³
Specific eight	blank	2.00
	control	1.55
	treated	1.51

Soil bulk density

Bulk density refers to the soil mass per unit volume, encompassing solid soil particles and soil pores. The concept is connected to porosity and the quantity of Water present in the soil, known as water content (USDA NRCS, 2019). Low porosity results in high bulk density and water content, suggesting dense soil. Table 4 shows a 0.04 g/cm³ increase in bulk density because when single-use masks break down into microplastics, they can accumulate within the soil (Zhao et al., 2021). As microplastics are heavier than organic soil components, such as plant fiber, the build-up of microplastics within the soil can raise soil bulk density and compact the soil structure. The effect of microplastic pollution on the density of loamy soil can differ based on the type of microplastics, the quantity that breaks down into the soil, and other specific environmental conditions (Ingraffia et al., 2022).

Soil porosity

Porosity is the ratio of pores inside the soil to the total soil volume, comprising water- and air-filled macrospores. Table 5 shows that the treated loamy soil has lower porosity than the control soil, which can occur because, over time, disposable masks that break down into microplastics can build up in the upper soil layer. This build-up can block soil pores, reducing soil porosity. It can modify the soil structure by altering its texture and physical composition and hindering water circulation, gas exchange, and plant root development (Guo et al., 2022). Furthermore, microplastics from disposable masks can interact with soil chemicals and nutrients. This disturbance could disrupt the nutritional equilibrium and activity of soil microbes, which are essential for soil health. Additionally, reducing soil porosity can enhance soil density and increase bulk density (Lozano et al., 2021).

Table 4. Bulk density of loamy soil

Parameter	Sample	gram/cm³
Bulk density	blank	0.53
	control	0.98
	treated	1.02

Table 5. Porosity of loamy soil

Parameter	Sample	%
Porosity	blank	79.83
	control	63.10
	treated	61.63

Soil c-organic

Organic carbon, often known as C-organic, is a vital factor in determining soil quality and health. It serves as an energy source for soil organisms and enhances the availability of plant nutrients. It includes organic materials derived from deceased species, such as litter, decomposed organic waste, and humus, as well as living organisms. Organic carbon can enhance the soil's physical, chemical, and biological characteristics to promote plant growth. The research findings in Table 6 show that the C-organic content in the treated loamy soil decreased by 10.18% after 45 days of treatment, starting from an initial value of 22.56% in the control soil sample. The blank sample has a lower concentration than the control sample due to the absence of plants. Microplastics hinder the functioning of soil organisms in loamy soil. Disposable masks include extra components, such as dyes or adhesives. If these masks partially or entirely break down in the soil, their chemicals may react with organic matter and impact soil quality. These chemical reactions might reduce the organic carbon content in the soil. When single-use masks break down on the soil surface, they can create a layer that blankets the soil. This layer can hinder air and water passage between the soil and the surrounding environment. Soil surface coverage might decrease the activity of crucial microorganisms involved in organic matter decomposition and C-organic production in the soil. Soil contaminated by disposable masks shows reduced biological activity and decreased organic carbon content (Kim et al., 2021). Assuming disposable masks are made of biodegradable organic materials such as cotton fibers or cellulose, they have the potential to blend with and become entrapped in the loamy soil. This contamination can reduce soil quality and impact its capacity to store and retain organic carbon. The notable reduction in C-organic content, both living and non-living organisms, probably results from reduced soil microbe production from microplastics. Earthworms and microorganisms may die from the microplastics in

Table 6. C-organic of loamy soil

Parameter	Sample	%
C-organic	blank	10.55
	control	22.56
	treated	12.38

the treated soil. Furthermore, the soil's capacity to mineralize minerals impacts the organic content of the soil, as soil minerals are connected to organic matter. Aside from organic matter, inorganic soil components help regulate the soil's capacity to assimilate various nutrient sources. Specific inorganic components undergo intricate interactions to enhance the solubility of other nutritional elements, increasing their absorption by plant roots (Lehmann et al., 2021).

Microplastics identification on loamy soil

The research findings show the existence of microplastic particles in the treated loamy soil samples. Various analytical methods detected microplastics, i.e., plastic fragments smaller than 5 mm. Particle fraction separation methods were used to isolate microplastic particles from other soil particles. This procedure utilized water, NaCl salt solution, or solutions with greater density than microplastic to separate the microplastic particles by floating them. After the separation procedure, visual observations were performed using a stereomicroscope. The isolated particles were carefully examined to detect unique characteristics of microplastics, such as irregular forms, vivid colors, or indications of erosion on their surfaces (Shim et al., 2016). The investigation utilizing scientific procedures confirmed the existence of microplastics in the loamy soil samples. This discovery enhances the proof of microplastic pollution in loamy soil, which may affect the soil ecology and organisms that depend on this habitat. Table 7 indicates that no microplastics were found in the control reactor. Meanwhile, the treatment reactor contained microplastics ranging from 0.3 mm to 1.34 mm in size (Figure 3). Additionally, the particle concentration in reactor 1 was 0.67 ± 0.58 particles per milliliter (part/ml). The average result from each sample drop in reactor 1 is 0.67, while the standard deviation is 0.58. The standard deviation should be smaller than the average to reflect the relevance of microplastics in each reactor. Reactors 2 and 3 generated microplastic concentrations of around 1.33 ± 0.58 part/ml. The many processes that take place as disposable masks break down cause the high concentration of microplastics in the loamy soil. Several factors affect the concentration of microplastics in each reactor, such as soil mobility, microorganisms' ability to break down compounds, percolation

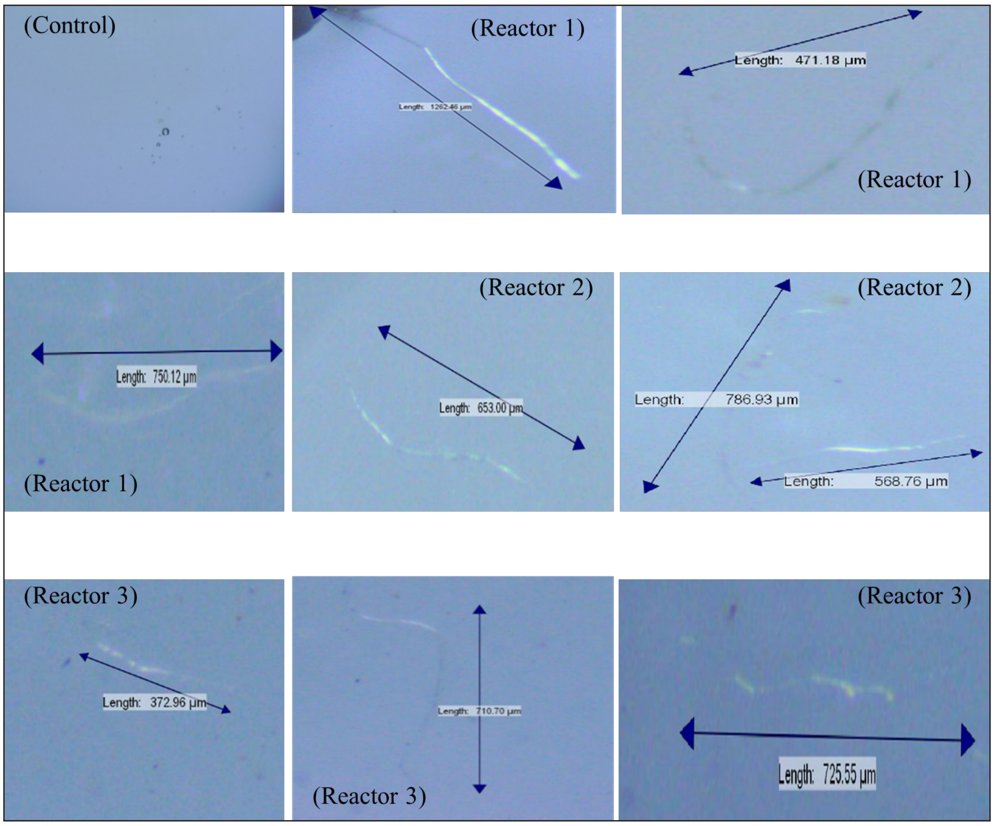

Figure 3. Microplastics (PP) in fiber form in loamy soil

Table 7. The results of microplastic identification in soil

Reactor	Day 0	Day 45		
		Particle (part/ml)	Type	Particle size (mm)
Control	unidentified	unidentified	unidentified	Unidentified
1	unidentified	0.67±0.58	fiber	0.51±1.26
2	unidentified	1.33±0.58	fiber	0.37±0.77
3	unidentified	1.33±0.58	fiber	0.73±1.34

from irrigation, and nutrient availability in the soil. Although the reactors have comparable components and percolation processes, they experience uncontrollable changes in movement. Microplastics in loamy soil can have major impacts on soil ecosystem balance by changing soil structure and porosity, influencing plant growth and development, and affecting soil organisms such as bacteria and earthworms. Moreover, the build-up of microplastics in loamy soil might impact groundwater quality via percolation processes (Rai et al., 2023)

CONCLUSIONS

Microplastics in loamy soil hinder organism activity following a 45-day treatment. This study shows alterations in the micro-macronutrient content of the soil. The mineral Si concentration decreased by 1.22% from the control to the treated soil. The C-organic content in the loamy soil decreased by 10.18% between the control and treated reactors. A decrease in porosity of 1.47% was observed when comparing the control and treated soil. Microplastics in the size range of 0.3±1.34 mm and of the fiber type were detected in the treated soil (R1, R2, and R3) along with these modifications.

Microplastics found in loamy soil from disposable mask waste can modify the soil's qualities, as seen by variations in nutrient levels and physical attributes. Additional study is required to address the management of disposable mask waste due to the extensive use of single-use masks as personal protection equipment.

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