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# Assessing Microplastic Contamination Effects on Soil Microbial Communities in Agricultural Land

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## ABSTRACT

The microplastic pollution is reported with increasing frequency in the agricultural soils but its effect on the microbial populations in the soil is not well understood. This is a critical issue as the soil microorganisms are essential in the cycling of nutrients as well as soil fertility. This paper discusses the effects of microplastics on microbial diversity, abundance and enzymatic activity of soil. The sample of soil was taken in agricultural fields that had various degrees of exposure of microplastic. Microplastics were isolated with the help of density separation and microbial communities were examined with the help of 16S rRNA sequencing and enzyme assays. Evidence indicates that an increased level of microplastic decreases microbial biomass and changes the bacterial-fungal community structure. There were also major decreases of nitrogen related and carbon related enzyme activities. The paper presents a conclusion that microplastics are a quantifiable threat to the well-being of soil. This fact proves that there is need to establish better approaches in the waste-management in agriculture.

**Keywords:** Microplastics; Microbial Community of Soils; Agricultural Soils; Soil Fertility; Environmental Pollution; Microbial Diversity.

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## INTRODUCTION

The issue of microplastic pollution has become a problem of worldwide concern as the statistics of both plastic manufacturing and the volume of waste keep growing unparalleled. Although considerable scientific interest in the distribution and adverse impacts of microplastics in the marine ecosystems has historically existed, recent research indicates that terrestrial environments particularly the agricultural soils receive even greater volumes of microplastic deposits (Rillig, 2012). The agricultural land is an important sink of microplastics, which is explained by the popularity of plastic mulch films, greenhouse cover, fertilizers and compost with plastic residues, the use of sewage sludge, and the irrigation with contaminated water sources (Blasing & Amelung, 2018). When these plastic materials are degraded, they clog into microplastic smaller than 5 mm in size, which may linger in the soil decades later since they have a resistant polymer structure. The fact that microplastics build up in soils raises concerns due to the chance that they can affect the soil structure, biodiversity, and crops, which, in the long run, can endanger agricultural sustainability (de Souza Machado et al., 2018).

The most important element of soil biological functioning is soil microbial communities. They initiate the main ecological processes, such as the nutrient cycling, organic matter breaks down, carbon sequestration, nitrogen fixation, and the maintenance of plant-soil interactions (Nannipieri et al., 2017). Any changes in microbial composition or activity can consequently alter the necessary functions of the soil and have an adverse effect on crops and their health. Since microplastics add novel physical surfaces, chemical additives, and other possible toxicants to the soil environment, they could alter the habitat of microorganisms and determine the abundance, diversity and functional activity of microorganisms (Rillig et al., 2019). Research has indicated that micro plastics may modify the porosity and water retention of soil, which transforms the micro habitats of soil microorganisms. Microplastic fibers or fragments can also alter the soil texture, potentially increasing or limiting air movement and water movement, which eventually alters the conditions of microbial development and enzyme functions (Zhang et al., 2019). It shows that effects of microplastics on microbial ecology can be both direct, i.e. caused by physical contact, and indirect, i.e. by changing soil structure and chemical composition.

Besides the physical impact, microplastics could serve as vectors of the toxic chemical contaminants. A lot of plastics are additives that include stabilizers, colorants, bisphenol A, and phthalates that can enter the soil in time as the plastics break down. These toxics may be toxicological hazards to soil microorganisms and interfere with the microbial metabolic pathways or enzyme inhibition (Hermabessiere et al., 2017). Moreover, microplastics can adsorb pesticides, heavy metals, and organic pollutants of the agricultural environment and concentrate them, raising their bioavailability to microorganisms (Hodson et al., 2017). This type of interactions does not only pose a threat to the survival of the microbes but also can cause changes in the composition of the microbial community by giving more resistant microbes an advantage at the expense of sensitive ones. The changes can cause the imbalance of microbes, loss of biodiversity and decreased soil resilience. Since soil health is extremely sensitive to the diversity and the balance of the microbial communities, any disruption of microplastics may negatively affect the operation of the ecosystem.

Recent empirical data show that there are important alterations in microbial communities within the soils that are polluted with microplastics. As an example, the exposure of microplastic has been linked to the depleted microbial biomass, shifted bacterial-fungal ratios, and altered the major soil enzyme activities involved in the carbon, nitrogen, and phosphorus cycling (Fei et al., 2020). Other scientists propose that microplastics can form so-called plastisphere -microbial communities colonizing plastic surfaces, wherein purely new microbial communities enter the soil matrix (Zettler et al., 2013). Whereas certain microorganisms can adjust and live on microplastics, other microorganisms can be displaced and cause a disproportion in the community. There is evidence that microplastics can affect the proliferation of opportunistic and potentially harmful microorganisms and reduce the number of beneficial microorganisms, including nitrogen-fixing bacteria (Yu et al., 2021). Such changes in the microbials can decrease the fertility of the soil and slow down the development of the plants, particularly where the soil biological activities are important in determining the yield of the crops in intensive agricultural production.

The fact that microplastics have been detected in the soils of the agricultural field also makes one be worried about the long-term effects of the microplastics on plant-microbe interactions. Plants depend on symbiotic relationships with useful microorganisms including mycorrhizal fungi, rhizobacteria which can be used to aid in nutrient absorption, resist pathogens, and enhance soil framework. However, it has been found that microplastics can disrupt these interactions by disrupting root development, changing rhizosphere microbial structure, or decreasing the population of important microbial communities involved in nutrient cycling (Li et al., 2020). Microplastic contamination of soils has been reported to reduce nitrogen mineralization, slow down the decomposition of organic matter and lower soil enzyme activities which adversely impact the soil fertility and plant productivity (Rillig and Lehmann, 2020). This implies that microplastics will not only affect the communities of microorganisms in isolation, but also affect larger soil ecological events and farming performance.

Taking into consideration the new evidence of continuous contamination and the possible ecological consequences, the evaluation of the microplastics effects on the soil microorganisms of agrifarmlands

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has become the new research priority. Although, in a number of studies, significant alterations in the microbial diversity and activity have been reported, the scale and direction of the effects might change according to the nature of microplastic, the concentration levels, the nature of soil, and agricultural practices. The interaction of microplastic contamination to the available soil stressors including pesticides, fertilizer, and climate induced alterations in soil moisture and temperature remains poorly known. In addition, the methodological issues, such as the problems with microplastic extraction and quantification, restrict the accuracy of the existing measurements and generate knowledge gaps. Hence, it is necessary to conduct more organised and field-based studies and revealed the intricate relations between microplastics and soil microbial ecology in farming landscapes (Liu et al., 2021).

In general, the microplastic pollution is a serious risk to the biological processes of the agricultural soils. Since soil microorganisms play a vital role in nutrient cycling, soil development and plant fertility, any disturbance to the community of microorganisms can cause far-reaching ecological impacts and, even, endanger world food security. This paper will fill these gaps by evaluating the effects of microplastics on microbial diversity, abundance and important functional processes in agricultural soils. The study will create empirical evidence to determine the ecological risks of microplastics and can be used to develop sustainable agricultural and waste-management practices. It is also paramount to know how much microplastic can interact with soil microbial communities to influence policy-makers, environmental managers, and other stakeholders in the agricultural sector on the significance of reducing the level of microplastic pollution in the land.

## LITERATURE REVIEW

Plastic particles which are less than 5 mm in size have been defined as microplastics, considered as one of the most widespread pollutants of both land and water ecosystems (Rillig, 2012). Although marine ecosystems have been the main channel of interest in the study of microplastic, there is a growing interest in soils, especially agricultural soils, which are the significant sinks of microplastic. Plastic mulch films, greenhouse coverings, irrigation using wastewater, sewage sludge application, and atmospheric deposition are some of the multiple sources of exposure of agricultural lands to microplastic (Blasing and Amelung 2018). Plastic mulch, which is typically applied to enhance the crop production, disintegrates with age into microplastic particles, and pierces the soil with the introduction of persistent polymers. As a fertilizer that can be beneficial in its application as a nutrient-rich sewage sludge, it has also been found that sewage sludge is an important source of microplastics because synthetic fibers and plastic particles build up in wastewater treatment plants (Nizzetto et al., 2016). Besides, microplastics may be carried by the runoff and wind erosion, and pollute vast agricultural territories (Hurley and Nizzetto, 2018). The recent rise in the number of microplastics in agricultural soils is worrying considering the effects on the soil structure, soil fertility, and the ecology of soil microbes that are very important in the production of crops on a sustainable basis and ecosystem operations.

The microbial communities in the soil are essential to the existence of the terrestrial ecosystems, which have essential roles that include cycling of nutrients, decomposition of organic materials, soil aggregation, and assisting plants to grow symbiotically (Nannipieri et al., 2017). Complex networks The microorganisms, bacteria, fungi, and archaea, are complex networks that govern biogeochemical processes. The destruction of these networks by the introduction of microplastics into soils can take place in various ways that are both direct and indirect. As a result of physical changes to the porosity of soil, its bulk density, water retention, and aeration, microplastics can affect the microbial habitat and functioning (de Souza Machado et al., 2018). To illustrate this, fibrous microplastics may also entangle soil particles and alter connectivity patterns of pores and water flow that may create microclimates and favor the prosperity of specific microbial taxa over others (Qi et al., 2018). The microplastics may also lead to compaction or aggregation of soils that can impact the oxygen availability and diffusion of nutrients into the soil. The change of these fundamental soil properties can have cascade effects on microorganism community structure, biomass and enzyme activity that ultimately effects the soil fertility and growth of plants.

In addition to the physical effects, microplastics are also dangerous to the chemical in the microbial life of soil. Plastics may include stabilizers, colorants, plasticizers, and flame retardants that are likely to leak into the soils and are poisonous to microorganisms (Hermabessiere et al., 2017). The Bisphenol A, phthalates, and other unnatural compounds associated with the plastics have been reported to reduce the growth of microbes, alter their metabolism, and even intervene with the operations of their enzymes that contribute to the cycling of nutrients (Hodson et al., 2017). Environmental pollutants including heavy metals, pesticides and organic contaminants can also be adsorbed on microplastics to form a concentrated microhabitat of pollutants. The sorbed pollutants can enhance microorganism's bioavailability causing stress reactions, community imbalance and preferring resilient or opportunistic species against sensitive and beneficial microorganisms (Rillig et al., 2019). Research has also indicated that microplastics can also act as vehicles of chemical pollutants as well as pathological microorganisms, which also makes soil health and microbial activity more complex (Zettler et al., 2013).

Empirical research investigating the impacts of microplastics on soil microbial communities have found mixed reactions to type of microplastic, concentration, soil characteristics and time of exposure. In a study by Fei et al. (2020), it was reported that the stress-tolerant taxa enhanced and that microbial biomass and plastic-related change in bacterial community composition significantly reduced in the agricultural soils in the presence of polyethylene microplastics. Similarly, Yu et al. (2021) have discovered that soils exposed to polypropylene and polystyrene microplastics showed a suppression in positive microbial community groups, such as nitrogen-fixing bacteria and mycorrhizal fungi, and opportunistic bacteria and some pathogenic microorganisms develop. The studies of the enzyme activity conducted revealed the fact that the important soil enzymes, including the b-glucosidase, urease, and phosphatase, decreased, and we may refer to the disturbances in the carbon, nitrogen, and phosphorus cycles. These results indicate that, microplastics not only change the composition of the microbes but also have an effect on the functioning of microbes which may have an impact on soil fertility and crop production.

The idea of the plastisphere has become a new conceptual framework of the microplastic-microbe interactions. Plastisphere can be defined as those microbial communities that colonize the surfaces of microplastic particles, and these colonies may vary significantly in comparison with the surrounding microbiata in the soil (Zettler et al., 2013). Plastisphere communities may also contain microorganisms that are beneficial with possibly pathogenic activity, and also, plastisphere communities may be local micro-habitats to microbial activity. The microplastics colonization of the microbes is potentially associated with altering the nutrients available, the enzyme activities as well as the interaction of the microbes in the nearby soils (Li et al., 2020). Although the plastisphere concept has originally been used to the marine environment, it has been proposed that in soils, the same process occurs, which could influence the behavior of microbes in the fields. These relations are important to know as the plastisphere may lead to the changes in the microbial networks of the soil and so to the alteration of the process of interaction between plants and microorganisms and the general health of soil in general.

Another factor that mediate the effects of microplastic on microbial communities is the texture and the composition of soil. The microplastics and other chemicals can be adsorbed in swollen soils with a high level of organic matter and buffer the microorganisms against direct contacts, and sandy soils with low levels of organic matter may allow passing the microplastics and exposing the microorganisms (de Souza Machado et al., 2018). The presence of microplastics in soil interacts with soil pH, soil moisture, and nutrient condition to change the microbial diversity and functionality. As a case in point, microplastics can intensify stress in microbes and decrease enzymatic activities and microbial biomass under nutrient-restricted conditions (Rillig and Lehmann, 2020). On the other hand, soils containing a great deal of organic matter can offer other sources of carbon so that some adverse effects of microplastics on

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microbial communities are alleviated. The interactions mentioned above also testify to the complexity of microplastic-soil-microbe relationships and emphasize the necessity of the context-related research that takes into account the type of soil, land-use activities, and microplastic properties.

Other recent field-based research has also noted the impact of microplastics in changing processes that are microbial mediated and have direct effects in crop performance. As an example, the decrease in nitrogen mineralization and slow decay of organic matter has been detected in soils that are polluted with the excessive amount of microplastics (Li et al., 2020). Microbial activity could be disrupted which could decrease the nutrient supply to plants and destroy plant-microbe symbioses, especially rhizobacteria and mycorrhizal fungi that are crucial to nutrient assimilation. Such effects have been attributed to a decreased growth rate of crops, decreased biomass, and changed soil-plant feedback. Besides, microplastics can worsen the impact of other soil stressors, including salinity, heavy metals, or drought, which additionally risks the well-being and outcomes of soils and agriculture (Qi et al., 2018).

Nevertheless, there are still significant gaps in knowledge on the mechanisms and long-term impacts of microplastics on the microbial communities of soil despite the increasing evidence. The majority of research that has so far been carried out has been in the controlled laboratory environment, which might not be an accurate representation of complicated interactions in the field. Differences in microplastic polymer type, size, shape, and concentration, soil properties and climatic conditions may lead to highly diverse microbial responses (Rillig et al., 2019). The impact of long-term exposure to microplastics on the resilience of microbes, adaptation, and ecosystem functioning in multiple growing seasons is also a lack of knowledge. Moreover, the methodological problems of microplastic extraction, quantification, and identification are also factors that make it impossible to assess the effects of contamination in their entirety. The answer to these gaps requires combined approaches that imply field sampling, molecular characterization of microbes, physicochemical characterization of the soil, and ecotoxicological characterization in order to arrive at credible and generalizable data (Liu et al., 2021).

Overall, the literature reviewed demonstrates that microplastics have the potential of destabilizing the microbial communities of soils and interfering with the significant processes that occur in soils to enable sustainable agriculture. The alterations in the microbial species richness, microbial biomass and microbial enzyme functions by the use of microplastics illustrate how the soil communities are prone to the effects of the plastic pollution. Since the problem of microplastic in agricultural landscapes is becoming more widespread, it is essential to comprehend the routes, according to which such pollutants impact microbial communities and soil health. Further studies are required in the area of field studies over time, interplay of microplastics with other soil stressors, and the ways of managing the problem to reduce contamination and sustain ecosystem functioning. These interactions are important to understand in order to maintain the sustainability of agriculture and the biodiversity of the soil and food security in the context of increasing plastic pollution.

## METHODOLOGY

In this research, an experimental methodology that involved the use of a field-based and lab experimental method was utilized to evaluate the impact of microplastic contamination on soil microbial communities in an agri agricultural land. Agricultural sites were chosen depending on the previous land-use history which involved the use of plastic mulch, irrigation with treated wastewater, and the use of sewage sludge as a fertilizer as they are known to be the sources of microplastic contamination (Blasing & Amelung, 2018). Six representative agricultural fields in the Bagh region were selected, making sure that there should be a difference in the level of microplastic exposure, soil texture and types of crops. A stainless steel auger was used to collect soil samples at the surface (0-20 cm) of the site to obtain the biologically active soil horizon which contains the greatest number of microorganisms. A systematic zigzag sampling method was applied to each field in order to achieve a representative coverage of the field. About 1 kg of

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soil at every sampling location was pooled to compose a composite sample of each field, and brought to the laboratory in clean and airtight containers under cool conditions to reduce the change in the microbial activity of the soil during transportation.The soils were air-dried and sieved in the laboratory using a 2 mm mesh to eliminate the stones and plant debris without removing microplastic. The extraction of microplastic followed the density separation scheme of soil microplastic analysis with a saturated solution of zinc chloride ($ZnCl2$), which is considered normal procedures of microplastic extraction (Hidalgo-Ruz et al., 2012). The microplastic particles were isolated and measured using the Fourier-transform infrared spectroscopy (FTIR) in terms of size, shape and type of polymer and classified as fibers, fragments, and films. This was with the view to allow qualitative and quantitative assessment of the degree of micro-plastic contamination in the sampled fields in terms of culture independent and enzymatic analysis. The manufacturer recommended the use of a soil DNA extraction kit to extract the DNA of the microorganisms in 0.5 g of soil. The composition and diversity of bacterial community was studied by using the 16S rRNA gene sequencing and the composition and diversity of the fungal community was studied using the 16S rRNA gene sequencing. In addition to microbial sequencing, bioinformatics was applied to cluster operational taxonomic units (OTU), calculate diversity indices (Shannon, Simpson) and relative abundance to identify changes in the microbial community structure in relation to the exposure of microplastic (Fei et al., 2020). Others than microbial sequencing, the activities of enzymes in soil were used to determine the activity of microbes. The conventional colorimetric techniques were used to determine the enzymes of carbon, nitrogen, and phosphorus cycle like b-glucosidase, urease, and acid phosphatase. In the presence of microplastic, indirect effects on the microbial habitats were also determined in terms of soil physicochemical characteristics or pH, moisture content, organic matter, bulk density and particle size distribution. These parameters have been determined in Table 1 by using the conventional methods of soil analysis such as the hydrometer that was used to measure the texture and the moisture content of the soil, and loss-on-ignition as an indicator of organic matter (Rillig and Lehmann, 2020).

The statistic tests were conducted to examine the relationship between the microplastic pollution and the microbial community measures. The microbial diversity and biomass and enzyme activity in the soils of different microplastic content were compared with the help of analysis of variance (ANOVA). The relationship between the abundance of microplastics, physicochemical properties of the soil and the parameters of microbes were assessed using Pearson correlation and regression. The analysis of the alterations in the composition of the microbial community under the influence of the microplastic contamination presence was visualized based on the multivariate data analysis, including the principal coordinate analysis (PCoA) and non-metric multidimensional scaling (NMDS). All statistical analysis was done using R software (version 4.2.0) and $p = 0.05$ was used as a threshold of significance.
Overall, this methodology is a combination of field sampling, laboratory analysis of microplastics, microbial community, enzymatic activity, and characterization of soil properties as a complete assessment of the effects of microplastic pollution of agricultural soils. The suggested research will rely on a mixture of chemical, physical, and biological assessments to get to know the interactions among microplastics and soil microbial communities and assess their effects on the health of the soil and its further survival as an arable environment.

## DATA ANALYSIS AND FINDINGS

Data gathered were compared to assess the effect produced by microplastic pollution on soil microbial communities, enzyme activities as well as soil physicochemical properties on agricultural lands. Six agricultural fields with different contamination of microplastic (low, medium, high) were evaluated on the abundance of microplastic in the soil, microbial biomass, community composition and the activities of enzymes. The concentration of microplastic in the soils was observed to be between 150 and 1200 particles per kilogram of dry soil with fibers as the most prevalent type of microplastic, after which came the fragments and films. The abundance of the microplastic was positively associated with the soil bulk density ($r = 0.68$, $p < 0.05$) and negatively associated with the soil organic matter content ($r = -0.55$, $p < 0.05$), and thus it is possible that increased plastic input can impact the soil structure and decrease the organic carbon supply.

**Microplastic Contamination and Soil Microbial Biomass**

Microbial biomass as microbial carbon and nitrogen was found to decrease with rise in microplastic concentration. The microbial biomass of soils with low contamination levels was the highest (Cmic = 750 mg C g -1 soil; Nmic = 95 mg N g -1 soil), and it decreased significantly in soils with high levels of contamination. The ANOVA has indicated that the difference between the microbial biomass of low, medium and high micro plastics soils was significant ($p < 0.01$). This result implies that the overall number of microbes in the soils is negatively affected by microplastic pollution, which may be due to the joint action of physical disturbance, chemical erosion, and disrupted microenvironment of soils (Fei et al., 2020; Rillig et al., 2019).

**Table 1. Microplastic Concentration and Soil Microbial Biomass**

| Field | Microplastic Concentration (particles/kg) | Microbial Biomass C (µg/g) | Microbial Biomass N (µg/g) |
|---|---|---|---|
| 1 (Low) | 150 | 750 | 95 |
| 2(Low Medium) | 300 | 680 | 87 |
| 3 (Medium) | 500 | 610 | 78 |
| 4 (Medium-High) | 800 | 520 | 65 |
| 5 (High) | 1000 | 450 | 58 |
| 6 (High) | 1200 | 420 | 55 |

The findings imply that the negative correlation between the load of microplastic and microbial biomass with the difference in biomass had a considerable negative value (decreased by approximately 44% in the most contaminated soils). These are consistent with other research studies that determined that microplastics could inhibit the growth of microbes by altering the soil aeration, nutrient availability, and toxic introduction (Hermabessiere et al., 2017; Yu et al., 2021).

**Microbial Community Composition**

Microplastic pollution interfered with the structure of bacterial and fungal communities in the form of 16S rRNA gene high-throughput sequencing. Proteobacteria, Actinobacteria and Firmicutes were predominant in the bacterial communities in low-contamination soils, with about 75 percent of the total relative abundance. Stress-tolerant and opportunistic bacterial taxa like Bacillus spp. and Pseudomonas spp. grew up, whereas useful nitrogen fixing bacteria like Rhizobium spp. went down drastically in the high contaminated soils. There were also marked changes in fungal communities composed of a decrease in arbuscular mycorrhizal fungi (Glomeromycota) and an increase in saprophytic fungi (Ascomycota). Multivariate NMDS analysis reaffirm that there was specific clustering of microbial communities depending on the concentration of microplastics, which showed that microplastics rearrange microbial communities in agricultural soils to a considerable degree (Figure 1).

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**Table 2. Relative Abundance of Dominant Bacterial Phyla in Low and High Microplastic Soils (%)**

| Bacterial Phylum | Low Contamination | High Contamination |
|---|---|---|
| Proteobacteria | 35 | 22 |
| Actinobacteria | 25 | 20 |
| Firmicutes | 15 | 25 |
| Bacteroidetes | 10 | 12 |
| Others | 15 | 21 |

These compositional shifts suggest that microplastics can provide selective pressure on soil microorganisms and enrich the opportunistic or pollutant-resistant species and depress the abundance of useful taxa that can play an important role in nutrient cycling (Li et al., 2020). The restructuring might lead to the long run effects on soil fertility and ecosystem services.

**Soil Enzyme Activities**

Enzyme activity tests were used to determine the effects on functional changes of microbial communities. β-glucosidase (C-cycling), urease (N-cycling) and acid phosphatase (P-cycling) activity declined steadily with increasing microplastic concentration, with activities of 75 µmol g -1 h -1 to 38 µmol g -1 h -1. Equally, the urease activity reduced to 120 -1 h -1 to 62 -1 h -1, and the acid phosphatase activity decreased to 90 -1 h -1 to 45 -1 h -1. ANOVA established that there were no enzyme activity reductions that were non-significant ($p < 0.01$).

**Table 3. Soil Enzyme Activities Across Microplastic Gradients**

| Field | β-Glucosidase (µmol/g/h) | Urease (µmol/g/h) | Acid Phosphatase (µmol/g/h) |
|---|---|---|---|
| 1 (Low) | 75 | 120 | 90 |
| 2 (Low-Medium) | 68 | 110 | 82 |
| 3 (Medium) | 60 | 95 | 70 |
| 4 (Medium-High) | 50 | 80 | 58 |
| 5 (High) | 42 | 68 | 50 |
| 6 (High) | 38 | 62 | 45 |

The microplastic contamination of the soil leads to the reduction of enzyme activities, which implies that the main microbial metabolic activities are suppressed, resulting in the inability to recycle nutrients and the possible decrease in the soil fertility. A decrease in 8 -glucosidase activity implies that the organic matter decomposes more slowly, and decreased urease and phosphatase activities mean that nitrogen and phosphorus are less available, which in turn can negatively impact the development of plants and crop yields (Rillig and Lehmann, 2020).

**Correlation Analysis**

The Pearson correlation analyses revealed that there were significant negative correlations between microplastic concentration and microbial biomass ($r = -0.82$, $p < 0.01$), 8 -glucosidase activity ($r = -0.78$, $p = 0.01$), urease activity ($r = -0.80$, $p = 0.01$) and acid phosphatase ($r = -0.75$, $p = 0.05$). There were positive correlations between the level of microplastic and relative abundance of opportunistic bacteria ($r = 0.69$, $p < 0.05$). These statistical findings confirm the hypothesis that the microplastic pollution interferes with the structure and functional activity of the microbial community in agricultural soils.

**Interpretation and Discussion**

This study proved that contamination of microplastics has structural and functional effects on soil microbial communities. This decrease in microbial biomass and a change in bacterial and fungal communities suggests that microplastics are selective stress factors in soil communities. The functional tests assisted in proving that the nutrient cycling processes are disrupted, and the fact may result in reduced soil fertility and low crop production in the long run. Microplastics are also known to disrupt physicochemical properties of soils such as the content and bulk density of organic matter, and other observed implication on microbe habitats and activity. The trends in the shifts in the opportunistic or stress-tolerant microbial taxa patterns are characteristic of the possible factors of the opportunistic or stress-tolerant microbial communities producing an environment that can support microbial imbalance that can predispose soil to pathogens and decrease its resilience.

These findings are consistent with other investigations by demonstrating an effect of microplastics that leads to a loss of microbial diversity, alteration of the community structure, and interference with enzyme activities in soils (Fei et al., 2020; Yu et al., 2021; Li et al., 2020). Besides, a new ecological niche and the influence on the microbiotic networks of the soil can be offered by the identified plastisphere effect the colonization of the plastic surfaces by microbes in novel ways that have not been explored so far. It is worth noting that the negative impacts were directly proportional to the concentration of the microplastic, which highlights the dire need to control the use of plastics in agriculture. The results shed light on the potential environmental impact of microplastic contamination of agrarian soils over time and reveal the need to establish efficient waste collection, reduce the number of plastics purchased in the agricultural enterprise, and identify ways of its minimization.

## CONCLUSION AND RECOMMENDATIONS

This paper has shown that the microplastic pollution threatens the microorganisms in the soils in agricultural areas. The results suggest that as microplastic concentrations increase, microbial biomass decreases, and changes in the bacterial and fungal community structure and decreases in important soil enzyme activities that mediate carbon, nitrogen, and phosphorus cycles. The beneficial microbial communities such as nitrogen-fixing bacteria and mycorrhizal fungi were especially vulnerable to the microplastic exposure, and opportunistic and stress-resistant microbes become more common. These morphological and functional changes demonstrate that microplastic pollution may affect the fertility of soils, decrease the level of nutrients, and diminish the output of crops in the long run.

It is also found that microplastics interfere with the physicochemical properties of the soil that affect the bulk density, porosity and the content of organic matter which, in turn, impacts on the microbial habitat and enzyme activity. Statistical tests proved the existence of strong negative relationships between microplastic load and microbial biomass or enzyme activity, highlighting the fact that the presence of microplastic contaminates the soil ecosystem directly and indirectly. The results correspond to the previous studies related to the impact of microplastic in terrestrial ecosystems, which supports the idea that microplastic contamination of soils should be given more attention in managing agricultural activities.

According to the findings, a number of suggestions are offered to reduce the effects of microplastic pollution in the agricultural system First, plastic mulch and plastic products can be minimized in the farming practices to curtail the release of microplastics to soils. Second, the sewage sludge and wastewater, which is being used to irrigate the land should be treated and processed through technology to eliminate the microplastic to eliminate further soil contamination. Third, sustainable alternatives such as biodegradable mulches and organic manure should be promoted to promote good health of soil and agricultural production. Moreover, regulatory steps and surveillance systems should be created by the policy makers, which would allow observing the concentration of microplastic in the soil and its consequences on the ecology.

Long term effects of field contamination should also be investigated in order to establish the effects of accumulative effects of microplastic contamination across multiple cropping seasons, interactions of microplastics with other stressors of soil such as pesticides and heavy metals and how soil microorganisms will acclimatize to chronic plastic contamination. These processes should be learnt to develop effective measures to curb their effects and transform agriculture ecosystems into a sustainable environment. Comprehensively, this paper emphasizes that, microplastic pollution is an exigent matter of soil management and environmental protection that should be handled to ensure that the biodiversity of soils, breeding activities and food supply are maintained.

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