Volume 18, Issue 2, 152413 (1-10)

International Journal of Industrial Chemistry (IJIC)

https://dx.doi.org/10.57647/j.ijic.2024.1502.13

Microbial and organic carbon mineralization in saline soil aggregates under different microplastic concentrations

Zhen Liu*, Xiaolong Zhao, Wanyan Zhou, Yuanyuan Liu, Pingping Cao, Jiaxuan Wu, Xuerui Guo, Yupeng Xu

Cangzhou Academy of Agriculture and Forestry Sciences, Cangzhou, China.

*Corresponding author: liuzhen84575151@163.com

Original Research

Received:
2 March 2024
Revised:
20 April 2024
Accepted:
2 May 2024
Published online:
30 June 2024

Abstract:

Plastic products are widely used in various fields, but the lack of effective means of recycling and disposal has led to the spread of plastics in the form of particles throughout the ecosystem. To examine the impact of microplastics on saline soils, the study was verified experimentally by adding microplastics of different sizes and concentrations to saline soil samples. The results showed that 25 um microplastics decreased the dissolved organic carbon content of organic matter saline soil, but had little effect on high organic matter soil samples. On the other hand, 1 mm microplastics increased the dissolved organic carbon content of organic matter soil samples; the highest organic carbon content was found at a microplastic concentration of 1.92 g/kg. Meanwhile, microplastics of different sizes increased the microbial amount carbon content of the soil samples, with increases ranging from about 24.3% to 108.9%. In addition, small diameter microplastic particles increased the rate of organic carbon mineralization in saline soils by up to 38.5%. Large diameter microplastic particles decreased the rate of organic carbon mineralization by up to 32.2%. The results demonstrate that the microplastic particle size can indirectly influence the water stability aggregate content by affecting the soil organic carbon mineralization rate and the soil microbial biomass and carbon content. This study examines the relationship between microplastics and soil biochemical processes under the influence of both biological and abiotic factors, which is of great significance for understanding the potential impact of microplastic pollution on carbon sequestration.

Keywords: Polyethylene; Microplastics; Dissolved organic carbon; Organic carbon mineralization; Microbial biomass carbon; Soil aggregate; Degree of destruction

1. Introduction

Due to its advantages of low cost, high stability, and insulation, plastics have been employed extensively in many fields since their invention in the early 20th century. However, it is also because of the good stability of plastics that it is difficult to be naturally decomposed, bringing great harm to the ecological environment. According to Statista's data, the global production of plastics grew from 2.2 million tons in 1950 to 42.7 million tons in 2022, a 20-fold increase. However, less than 40% of plastic products can be effectively recycled [1–3]. Microplastics (MPs) particles are dispersed globally through air and water currents. MPs can significantly alter the microbial community and the composition of the soil when they get into it, which could ultimately have an effect on the stability of the local ecosystem [4–6]. Saline land ecosystems are particularly fragile compared to other lands. In order to investigate the effects of MPs on organic carbon mineralization (OCM) and microorganisms in saline alkali soil, the effects of different concentrations and sizes of MPs on soil microorganisms and OCM in saline alkali soil of Cangzhou City, Hebei Province, China were studied. Its purpose is to provide a foundation for improving saline ecosystems and MPs management.

The article is divided into four chapters. Chapter 1 is a literature review, which will give a brief description of the current research related to soil OCM and MPs. Chapter

2 will describe the experimental methods and materials. Chapter 3 will analyze the experimental results of OCM and microorganisms in saline soils under the effect of MPs. The last chapter will summarize the full study.

In addition to being a crucial nutrient for plant and microbial growth, soil organic carbon also has a big impact on soil composition and ecosystem resilience. OCM rates were influenced by aggregate size and tillage intensity, according to research by Wang et al. on the composition and dynamics of microbial communities in soil aggregates. The practice of conservation tillage suppressed OCM and reduced the abundance of functional genes associated with unstable carbon decomposition in aggregates [7]. Zhang and colleagues studied how plant apoplastic matter affected soil organic matter content. In addition, the results showed that the highest amount of soil OCM was found in the mowing and sealing areas with the addition of Artemisia coldis apoplastic matter, which were 3513.25 mg/kg and 2867.55 mg/kg, respectively. It can be concluded that plant apoplastic matter significantly increases the rate of OCM and the amount of cumulative mineralization of the soil [8]. Zhang and other scholars addressed the issue of the influence of soil biochemical properties and organic carbon structure on OCM by using Illumina sequencing and Fourier transform infrared spectroscopy of 16S rRNA gene. The findings indicated that the higher aromatic carbon content of Liaodong oak resulted in a reduction in soil OCM rate. The acidobacterial group was found to be associated with recalcitrant organic carbon structure, whereas ascomycetes and anamorphic bacilli were associated with unstable organic carbon structure, respectively [9]. T4-like phages were used in tests by Wei et al. to investigate the role of viruses in soil OCM. The findings of the experiment demonstrated that CO_2 efflux from soil rose with bacterial abundance but fell with the abundance of T4-like phages [10].

MPs is often less than 5 mm in diameter, which makes it easy to be ingested by organisms and then enter the food chain, posing a threat to the survival of plants and animals. Therefore, MPs pollution has attracted much attention in recent years. Liu et al. investigated how MPs affects the organic carbon cycle. The results showed that MPs stimulates microbial metabolic pathways in order to accelerate the biodegradation process of soluble organic matter, and the transformed soluble organic matter appeared to have low bioavailability, high stability, and aromaticity [11]. Xiao and other scholars studied the effect of MPs on fish lifespan. The results showed that MPs not only shortened the lifespan of fish, but also accelerated the development of age-related biomarkers. At the same time, MPs also induced oxidative stress, leading to liver dysfunction [12]. The question of how nanobubbles affect the movement of MPs in the ocean was investigated by Wang et al. The findings demonstrated that the addition of MPs to nanobubbles increased the measured mean particle size and concentration in the presence of nanobubbles [13]. Wang and his team investigated the environmental impact of biofilms formed by MPs and showed that MPs polymerized into biofilms could adsorb more pollutants than the original plastic, which then acted as a carrier to introduce the pollutants and attached microorganisms into aquatic environments and living organisms, resulting in more serious pollution [14]. In summary, MPs, as a pollution source of great concern, is widely distributed in the world. However, most of the current research on MPs focuses on its effects on the environment, plants and animals, but less on its effects on soil properties. Therefore, the study analyzed the ecological impacts of MPs from the perspectives of soil microorganisms and soil organic carbon, which provides a strong support for environmental protection.

2. Experimental materials and method

2.1 Laboratory materials and equipment

The experimental materials included saline soil (from Cangzhou City, Hebei Province, China, 116°44′3″ E 38°144′23″ N, average annual temperature 13°C, and 10°C accumulated temperature 4,349°C), polyethylene MPs, sodium hydroxide solution, barium chloride solution, hydrochloric acid, phenolphthalein, chloroform solution. The experimental equipment included medium-speed qualitative filter paper, constant temperature incubator, granulator, motorized vibrating sifter, and Aggregates analyzer. The experimental materials and equipment are shown in Table 1.

2.2 Experimental methods

Soil treatment: Saline soil was collected from 0 to 20 cm depth down and residual organisms were removed. The soil was allowed to air-dry and then screened using a sieve with

Table 1. Experimental materials and equipment.

Name	Model/Specification	Manufacturer
Polyethylene MPs	1 mm/25 um	China Petroleum & Chemical Corporation
Sodium hydroxide solution	0.1 mol/L	Self-prepared
Barium chloride solution	1 mol/L	Self-prepared
Hydrochloric acid	0.1 mol/L	Self-prepared
Phenolphthalein	Analytically pure	Wuxi Jingke Chemical Co.
Chloroform solution	10%-30%	Self-prepared
Medium-speed qualitative filter paper	/	Beijing Tianlian Harmonious Instrumentation Co., Ltd.
Constant temperature incubator	/	Shanghai Jiecheng Experimental Instrument Co., Ltd.
Granulator	/	Qingdao Konil Machinery Equipment Co., Ltd.
Motorized vibrating sifter	HY8411	Beijing Zhonghui Tiancheng Science and Technology Co., Ltd.
Aggregates analyzer	/	Shandong Lainde Intelligent Science and Technology Co., Ltd.

a diameter of 2 mm. Two groups of soil samples were created: a high organic matter soil was created by mixing the soil samples with organic fertilizer, and a low organic matter soil was created by leaving the soil samples alone. The pH and organic matter content of the high organic matter soil were about 8.2 and 33.9 g/kg, and the content of nitrogen and effective phosphorus/potassium were about 1.2 g/kg, 9.7 g/kg and 136.7 g/kg, respectively. In addition, the pH and organic matter content of the low organic matter soil were about 8.5 and 10.3 g/kg, and the content of nitrogen and effective phosphorus/potassium were about 0.7 g/kg, respectively, 7.5 g/kg and 125.5 g/kg, respectively [15–17]. In the experiment, the potted experiment is generally used to simulate the harm of environmental pollutants to plants, and it is difficult to plant potted plants with unmodified saline-alkali soil, so the potted experiment is not conducted in this study.

MPs treatment: It was cleaned using distilled water and filtered through medium speed qualitative filter paper, and finally dried at 30°C.

Cultivation method: A total of 20 treatments were set up, comprising two particle sizes, five MP concentrations, and two organic matter levels. Each treatment is repeated three times, with the exception of the blank control, which is conducted once. The MPs are to be mixed with two levels of organic matter in air-dried soil at the aforementioned concentration. The soil moisture content is then adjusted to 60% of the field capacity. The soil is then cultivated at 25°C in a constant temperature incubator for one week in order to activate the soil microorganisms. After the pre-cultivation period, the soil sample is to be granulated using a granulator in order to compress it into aggregates with a diameter of 2.5 mm. The aggregates with added MPs are to be placed in culture boxes, each containing 2 kg of aggregates. These are to be sealed with cling film and holes for soil respiration are to be drilled. The culture boxes are then to be placed in a 25°C constant temperature incubator for 6 months [18, 19]. Moisture should be added every five days using the weighing method. The soil aggregate mass and moisture content should be controlled to 25% during the experiment. The content of water-stable aggregates, microbial biomass carbon (MBC) content in aggregates, and mineralization characteristics of organic carbon in aggregates should be sampled and measured during the first, third, and fifth months of cultivation. The experimental grouping is shown in Table 2.

Measurement method: The force stabilizing aggregates were measured by dry sieving method, which was as follows: Initially, the top layer of the set of sieves had 200 g of air-dried aggregates soil samples. These were subsequently sieved using an electric vibrating sifter, and the soil samples on each layer of the sieve were gathered and weighed for spares. In addition to the sieve sizes of less than 0.25 mm, 0.25-0.50 mm, 0.50-1.00 mm, 1.00-2.00 mm, 2.00-5.00 mm, and more than 5 mm, the vibration frequency and duration were 1400 times/min and 10 min, respectively [20]. The water-stable aggregates were measured by the wet sieving method as follows: Firstly, the aggregates were dry sieved, then 50 g of agglomerate particles were weighed in each layer and soaked for 20 min, followed by oscillatory sieving, and the soil samples were collected and placed in an oven and dried at 105°C. The sieve diameters were 0.25-0.50 mm, 0.50-1.00 mm, 1.00-2.00 mm, and greater than 2 mm. The formula for calculating the content of force-stable and water-stable aggregates is shown in Eq. (1).

$$\begin{cases} DR_{0.25} = \frac{DMr_{0.25}}{Mr} \\ WR_{0.25} = \frac{WMr_{0.25}}{Mr} \end{cases} \tag{1}$$

In Eq. (1), $DR_{0.25}$ and $WR_{0.25}$ represent the content of force-stabilized and water-stabilized aggregates with diameters

Table 2. The experimental grouping situation.

Number	Organic matter level	Microplastic concentration (g/kg)	Microplastic diameter
Control group	No organic matter	0.00	/
LPP 1		0.06	25 um
LPP 2		0.64	25 um
LPP 3		1.92	25 um
LPP 4		3.20	25 um
LPP 5	Low organic matter levels	6.40	25 um
LGP 1		0.06	1 mm
LGP 2		0.64	1 mm
LGP 3		1.92	1 mm
LGP 4		3.20	1 mm
LGP 5		6.40	1 mm
HPP 1		0.06	25 um
HPP 2		0.64	25 um
HPP 3		1.92	25 um
HPP 4		3.20	25 um
HPP 5	High organic matter levels	6.40	25 um
HGP 1		0.06	1 mm
HGP 2		0.64	1 mm
HGP 3		1.92	1 mm
HGP 4		3.20	1 mm
HGP 5		6.40	1 mm

greater than 0.25 mm, respectively. $DMr_{0.25}$ and $WMr_{0.25}$ denote the weight of force-stabilized and water-stabilized aggregates with diameters greater than 0.25 mm, respectively. Mr denotes the total weight of aggregates. The formula for calculating the degree of agglomerate destruction is shown in Eq. (2).

$$PAD = \frac{DR_{0.25} - WR_{0.25}}{DR_{0.25}} \times 100\% \tag{2}$$

In Eq. (2), PAD represents the degree of destruction of aggregates. The average weight diameter of aggregates is calculated in Eq. (3).

$$MWD = \sum_{i=1}^{n} x_i \omega_i \tag{3}$$

In Eq. (3), MWD denotes the average weight diameter of the aggregates, x_i denotes the average diameter of the ith aggregates particle. ω_i represents the percentage of mass of the ith aggregates particle.
The OCM rate was measured by the slurry absorption method by first weighing 50 g of the soil sample and placing it in an incubation bottle, followed by adding 5 ml of sodium hydroxide solution (0.1 mol/L) to the beaker and placing the beaker slowly on the soil. The culture flask was then sealed using cling film and sealing film. For 35 days, the sealed culture flasks were cultured at 25°C in an incubator maintained at a constant temperature. Water was replenished regularly during the incubation period. On the 1st, 3rd, 6th, 9th, 16th, 21st and 35th days after incubation, the beaker was removed and the solution was transferred to a conical flask and the beaker was washed with distilled water. Following the addition of phenolphthalein and 2 milliliters of barium chloride solution (1 mol/L), the solution was titrated with hydrochloric acid (0.1 mol/L) until the red hue vanished, at which point the quantity of hydrochloric acid used was noted. At the same time, fresh sodium hydroxide solution was added to the beaker [21, 22]. Based on the hydrochloric acid consumption, the amount of carbon dioxide released from the soil samples was calculated. Soil microbial content was then measured using chloroform fumigation method. Soil MBC was calculated as shown in Eq. (4).

$$MBC = \frac{Ec}{Kc} \tag{4}$$

In Eq. (4), MBC denotes the soil MBC content, and Ec denotes the difference between the organic carbon extracted by fumigation and the organic carbon not extracted. Kc represents the conversion coefficient, which takes the value of 0.45.

3. Effect of microplastics on saline soil properties

The soil aggregate stability, microbiological content, and OCM of MPs were examined in order to examine its impact on saline soils.

3.1 The effect of microplastics on soil aggregates

The effect of MPs on the average weight diameter of force stabilized aggregates at different organic matter levels is shown in Fig. 1.
The average weight diameter of the aggregates in the PP 1 group increased by roughly 16.2% when compared to the control group in Fig. 1(a), where the average weight diameter of the aggregates at the early stage of incubation gradually decreased with the increase of MPs concentration at low organic matter level. The mean weight diameter of the aggregates reduced as the MPs concentration grew throughout the later stages of incubation and subsequently increased again. By the fifth month, the MPs-added soil samples' average weight diameter of aggregates had decreased by at least 8.3% compared to the control group's. In Fig. 1(b), the mean weight diameter of aggregates in the control soil samples was consistently larger than that of the MPs-added soil samples at high organic matter levels, and the difference gradually increased over time. At month 5, the average weight diameter of aggregates of MPs-added soil samples were all at least 14.3% lower compared to the control group. These results indicate that MPs reduced the average weight diameter of aggregates in saline soils regardless of the organic matter level. The effect of MPs concentration on the degree of disruption of soil aggregates is shown in Fig. 2.
In Fig. 2(a), at low organic matter level, when MPs content does not exceed 0.06 g/kg, it decreased the degree of destruction of soil aggregates by up to 15.7%. Whereas, when MPs content exceeds 0.64 g/kg, it increased the degree of destruction of soil aggregates to some extent. At the 5th month, MPs at a concentration of 0.64 g/kg had the greatest

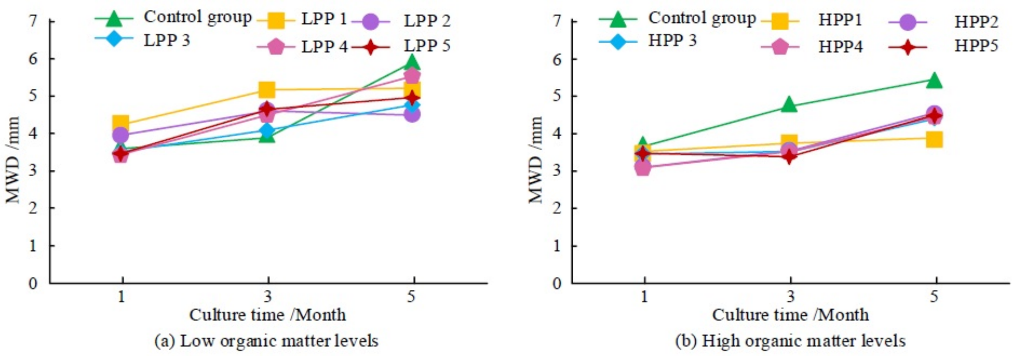

Figure 1. Average weight diameter of the force-stabilizing aggregates at different microplastic concentrations.

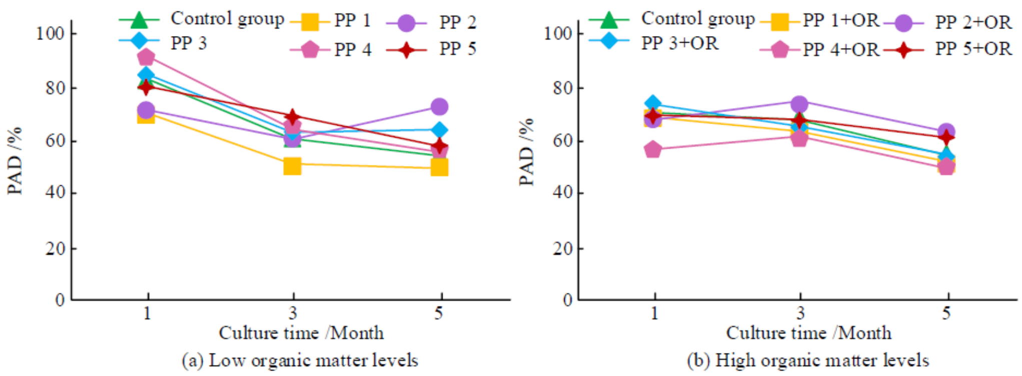

Figure 2. Effect of microplastic concentration on the destruction degree of soil aggregates.

effect on the degree of destruction of soil aggregates, increasing it by about 32.7%. In Figure. 2(b), a small amount of MPs also reduced the degree of soil aggregate destruction at high organic matter levels. At month 5, only MPs at concentrations of 0.64 g/kg and 6.40 g/kg increased the degree of soil aggregate destruction by 10.5% and 7.1%, respectively. The above results indicated that MPs would increase the degree of soil aggregate destruction to some extent. The effect of different diameters of MPs on low organic matter soil aggregates is shown in Fig. 3.

In Fig. 3(a), in the fifth month of cultivation, the degree of aggregate damage of soil samples with added MP particles with a diameter of 25 μm has basically increased. In Figure. 3(b), during the cultivation process, the degree of aggregate damage in the soil sample with the addition of MP particles with a diameter of 1 mm was consistently higher than that of the control group, with a maximum increase of 27.8%. The above results indicated that in low organic matter saline alkali soil, MP particles of different diameters can improve the degree of aggregate destruction to a certain extent. The effect of different MPs diameters on high organic matter soil aggregates is shown in Fig. 4.

In Fig. 4(a), the agglomerate disruption of soil samples spiked with MPs particles with a diameter of 25 um was significantly higher at concentrations of 0.64 g/kg and 6.40 g/kg during the 5th month of incubation. The remaining

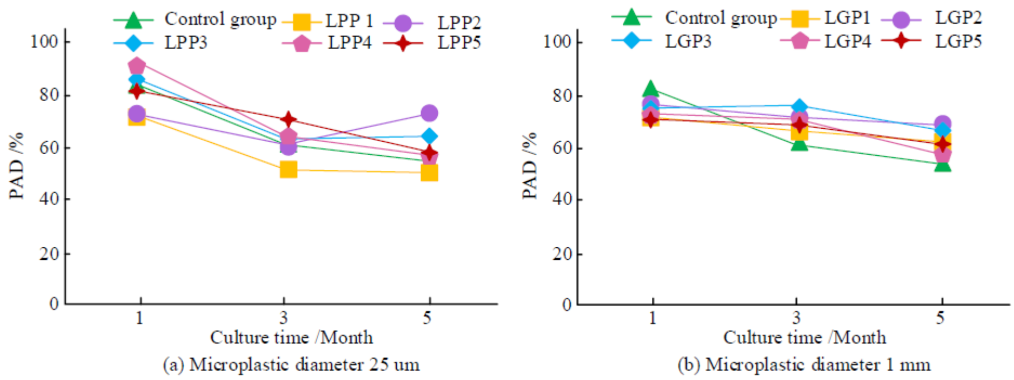

Figure 3. Effects of different microplastic diameters on low organic matter soil aggregates.

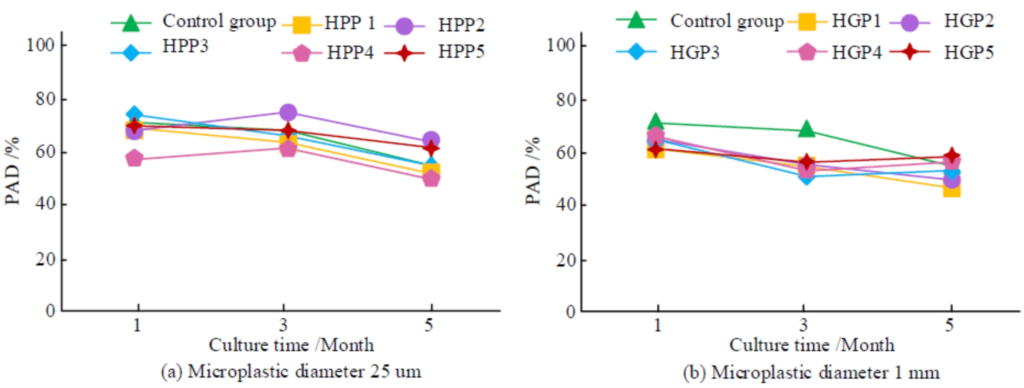

Figure 4. Effects of different microplastic diameters on high organic matter soil aggregates.

soil samples showed little change compared to the control. The agglomeration disruption of soil samples containing MPs particles with a diameter of 1 mm was consistently lower—by as much as 24.3%—than that of the control group throughout the incubation period, as shown in Fig. 4(b). The above results suggested that in high organic matter saline soils, small-diameter MPs particles may increase the degree of soil agglomerate destruction, while large-diameter MPs particles may reduce the degree of agglomerate destruction to some extent.

3.2 The effect of microplastics on soluble organic carbon

The effect of MPs on dissolved organic carbon (DOC) at low organic matter level is shown in Fig. 5.
When MPs had a diameter of 25 um, as shown in Fig. 5(a), the DOC content at the start of the culture rose as MPs concentration increased. Additionally, following three months of culture, all groups' DOC content dramatically dropped. Furthermore, at five months of incubation, all experimental groups' DOC content dropped considerably—down to 40.2%—when compared to the control group. In Fig. 5(b), in the low organic matter environment, when the diameter of MPs was 1 mm, the change of DOC content was not obvious at the early stage of incubation. After 5 months of incubation, only 0.06 g/kg and 1.92 g/kg concentrations of MPs had significant effects on DOC content. The above results indicated that in saline soils with low organic matter levels, small diameter MPs particles significantly reduced the DOC content of the soil. The effect of MPs on DOC at high organic matter level is shown in Fig. 6.
In Fig. 6(a), when the MPs diameter was 25 um, at the early stage of incubation, the DOC content of all experimental groups, except the experimental group with MPs concentration of 0.06 g/kg, was slightly higher than that of the control group. With the exception of the experimental group, which had a MPs concentration of 3.20 g/kg, all groups' DOC content was lower after three months of incubation than that of the control group. Additionally, there wasn't much of a difference between the groups' DOC contents after five months of incubation. At the early stage of culture, there was minimal variation in the DOC content between the experimental and control groups in Fig. 6(b), when the diameter of MPs was 1 mm. In addition, after 5 months of culture, with the increase of MPs concentration, the DOC content increased and then decreased. The highest DOC content of 23.4 mg/kg was observed when the MPs concentration was 1.92 g/kg. The aforementioned findings showed that in high organic matter saline soils, the concentration of large-diameter MPs particles first increased and subsequently decreased the DOC content.

3.3 Microplastics affecting microbial biomass carbon in soil samples

The effect of MPs on MBC in low organic matter soil samples is shown in Fig. 7.
In Fig. 7(a), in the low organic matter soil samples, the MBC content at the beginning of incubation decreased and

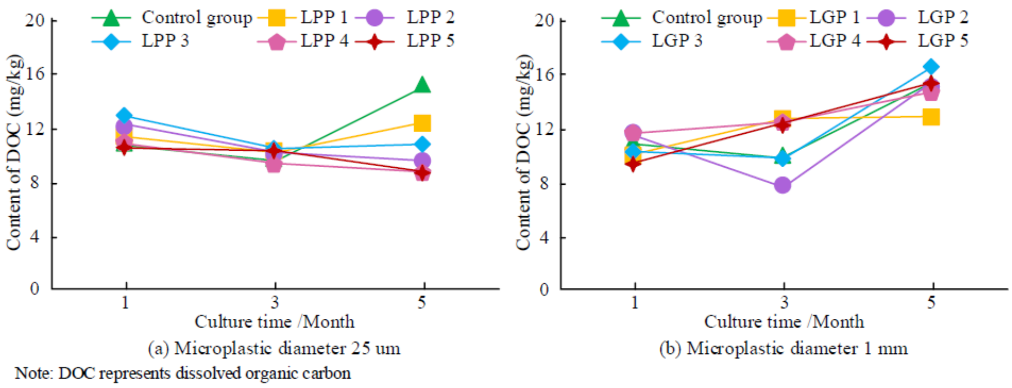

Figure 5. Effect of microplastics on dissolved organic carbon at low organic matter levels.

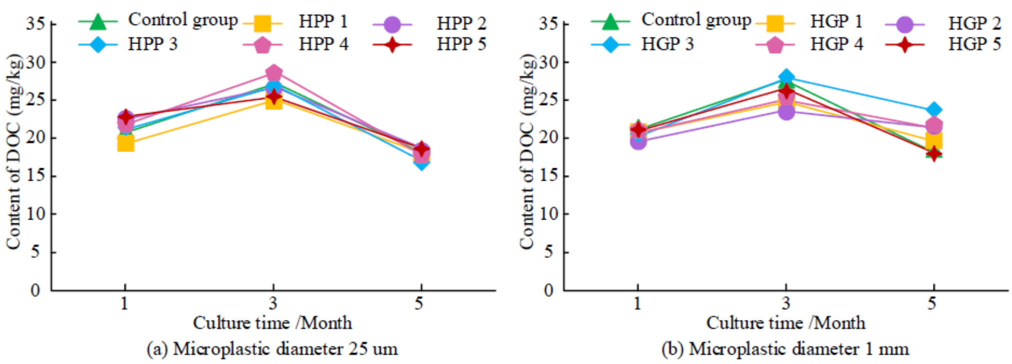

Figure 6. Effect of microplastics on dissolved organic carbon at high organic matter levels.

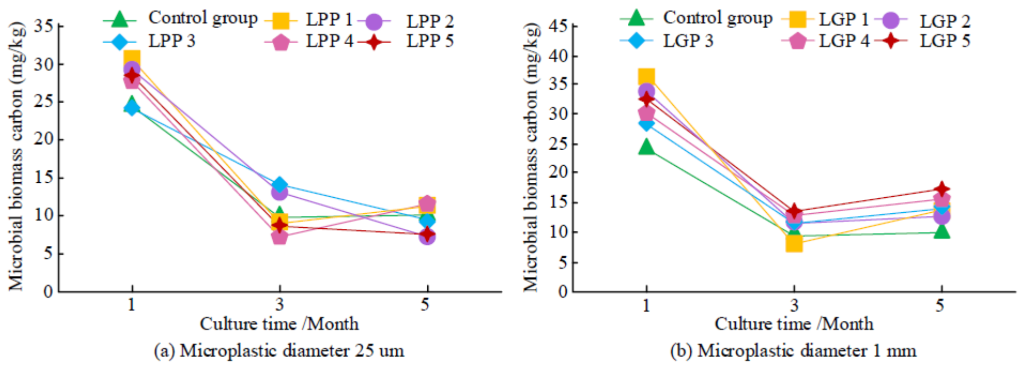

Figure 7. Effect of microplastics on microbial biomass carbon in low organic matter soil samples.

then increased with the increase of 25 um MPs concentration. After 5 months of incubation, the MBC content was only higher in PP 1 and PP 4 groups than in the control group. The MBC content of the experimental groups was higher than that of the control group in Fig. 7(b), when the diameter of MPs was 1 mm, and it initially declined and subsequently increased with an increase in concentration. Following five months of culture, the experimental groups' MBC contents exceeded those of the control group and essentially rose as the concentration of MPs grew. The MBC content was 17.5 mg/kg at a MPs concentration of 6.40 g/kg. The above results indicated that in low organic matter saline soils, small diameter MPs particles have a significant effect on MBC content in relation to its concentration. While large diameter MPs particles increase the MBC content of saline soil. The effect of MPs on MBC in high organic matter soil samples is shown in Fig. 8.

In Fig. 8(a), the addition of 25 um of MPs at the start of the incubation period dramatically decreased the MBC content of the soil in high organic matter soil samples; nevertheless, the MBC content rose as the MPs concentration increased. Following five months of incubation, each experimental group's MBC content exceeded that of the control group and essentially rose as the concentration of MPs increased. When the MPs concentration was 6.40 g/kg, the MBC content was 28.3 mg/kg. In Fig. 8(b), MPs particles with a diameter of 1 mm had little effect on the MBC content at the early stage of culture. Each experimental group's MBC content rose dramatically after five months of incubation when compared to the control group; the increase was higher in the groups with higher MPs concentrations. It can be seen that in high organic matter saline soil, MPs will increase the MBC content in soil.

3.4 The effect of microplastics on soil organic carbon mineralization

The effect of MPs on the OCM rate of low organic matter soil samples is shown in Fig. 9.

In Fig. 9(a), at low organic matter levels, the OCM rates of the experimental groups were all significantly increased with the addition of MPs particles with a diameter of 25 um compared to the control group. Among them, the greatest OCM rate enhancement was observed at MPs concentration of 6.40 g/kg, which increased by about 38.5%. In Fig. 9(b), when the MPs diameter was 1 mm, the OCM rates of all experimental groups except the GP 1 group decreased compared to the control group. The greatest decrease in mineralization rate was observed when the concentration was 3.20 g/kg, which decreased by about 31.1%. The effect of MPs on the OCM rate of high organic matter soil samples is shown in Fig. 10.

In Fig. 10(a), at high organic matter levels, the OCM rates of the experimental groups all increased significantly after the addition of MPs particles with a diameter of 25 um. Among them, when the MPs concentration was 3.20 g/kg, the mineralization rate increased the most, by about 15.9%. In Fig. 10(b), when the MPs diameter was 1 mm, the OCM rates of the soil samples in the experimental group were

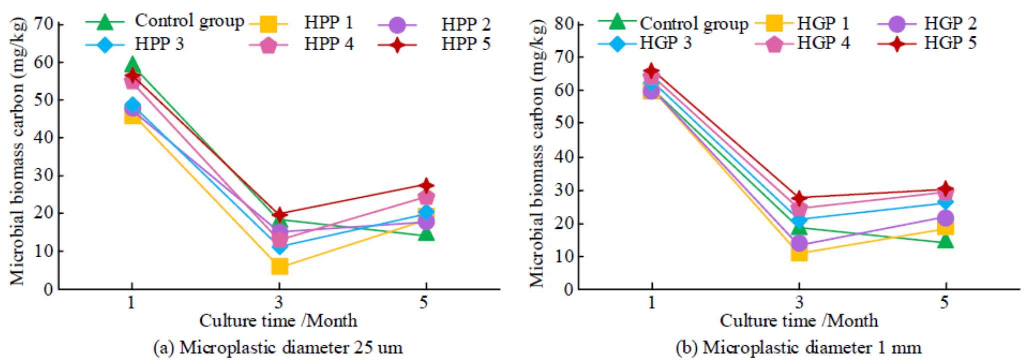

Figure 8. Effect of microplastics on microbial biomass carbon in high organic matter soil samples.

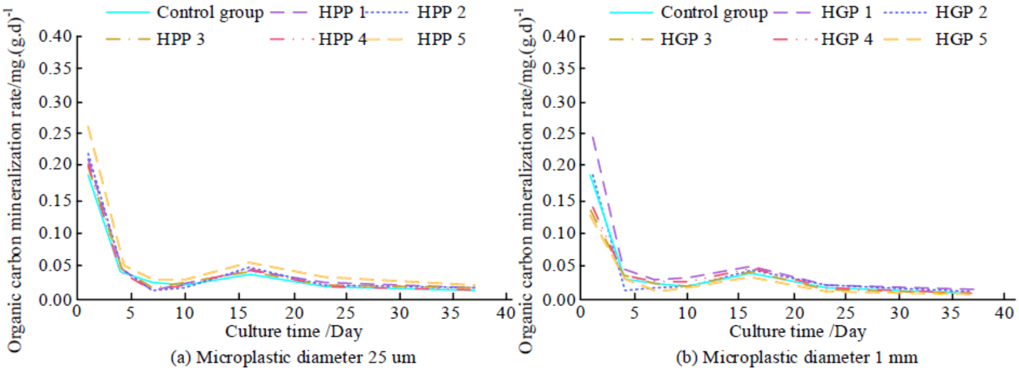

Figure 9. Effect of microplastics on the mineralization rate of organic carbon in low organic matter soil samples.

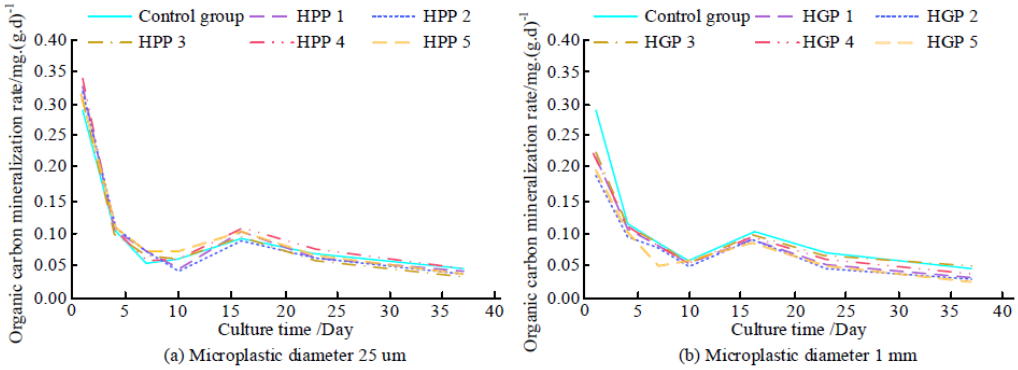

Figure 10. Effect of microplastics on the mineralization rate of organic carbon in high organic matter soil samples.

all reduced compared to the control group. The greatest decrease was observed when the MPs concentration was 0.64 g/kg, which decreased by about 33.2%. The above results indicated that small-diameter MPs particles increase the OCM rate of soil in both high and low organic matter saline soils, while large-diameter MPs particles decrease the OCM rate. Fig. 11 displays the total amount of OCM in low organic matter soil samples.

With the exception of the PP 3 group, all experimental groups showed cumulative OCM greater than that of the control group when the MPs diameter was 25 um, as shown in Fig. 11(a). When the MPs concentration was 0.64 g/kg, the maximum cumulative mineralization of organic carbon was recorded among them, at 700 mg/kg. Only the GP 1 and GP 5 groups' cumulative mineralization of organic carbon was higher than the control group's in Fig. 11(b), when the MPs diameter was 1 mm. The highest cumulative OCM of 650 mg/kg was found in GP 5. The cumulative OCM of high organic matter soil samples is shown in Fig. 12.

In Fig. 12(a), MPs particles with a diameter of 25 um had little effect on the cumulative OCM in a high organic matter saline soil. However, when the MPs concentration was higher, the OCM accumulation was slightly elevated. When the MPs diameter was 1 mm, as shown in Fig. 12(b), the cumulative mineralization of organic carbon in each experimental group was less than that of the control group. Additionally, the cumulative mineralization of organic carbon first dropped and subsequently increased as the concentra-

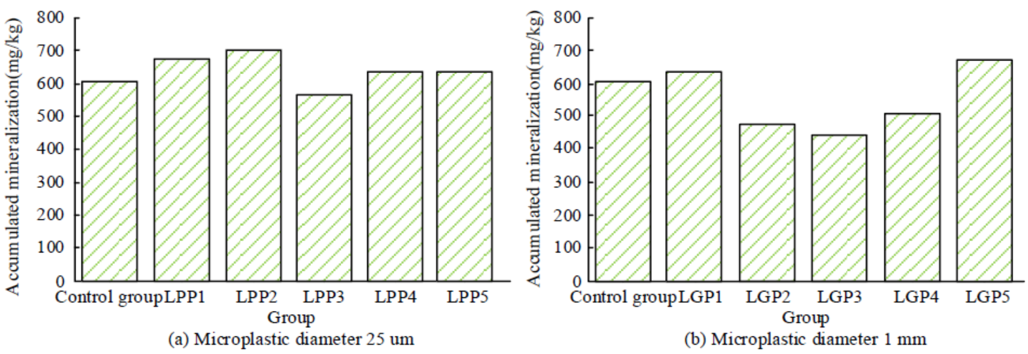

Figure 11. Accumulation of organic carbon mineralization in low organic matter soil samples.

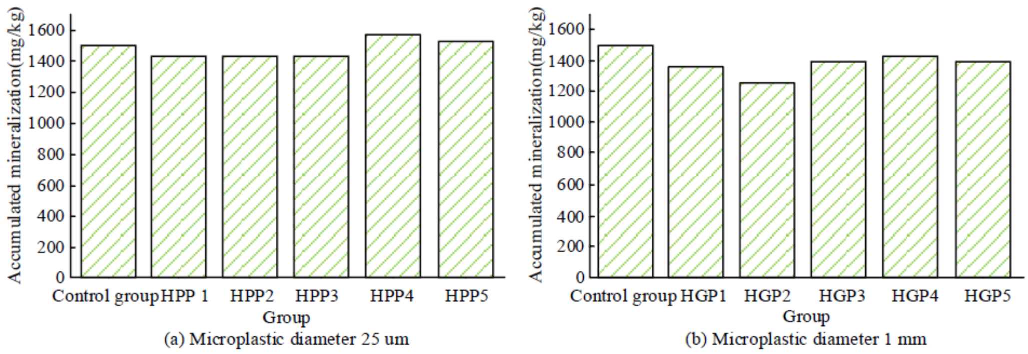

Figure 12. Accumulation of organic carbon mineralization in high organic matter soil samples.

tion of MPs increased. The minimum cumulative mineralization of organic carbon was 1273 mg/kg at a concentration of 0.64 g/kg. This indicated that the large diameter MPs particles would decrease the cumulative mineralization of organic carbon in soils with high levels of organic matter salinity.

4. Conclusion

The accumulation of plastic in the natural environment has a significant impact on the environment. This study aimed to investigate the effects of MPs on microorganisms and OCM in saline soil by conducting experimental verification. Therefore, to investigate the effect of MPs on microorganisms and OCM in saline soil, the study was conducted to experimentally validate. The experimental results indicated that in low organic matter saline soil, MPs can reduce the stability of soil aggregates to a certain extent. This reduction was closely related to the concentration of MPs. In addition, MPs also reduced the DOC content in low organic matter saline soil and increased the MBC content. MP particles with a diameter of 1mm had a more significant enhancement effect on MBC. With regard to the OCM rate, the 25 μm MPs particles exhibited a 38.5% increase in the mineralization rate of low organic matter saline soil. Conversely, the 1mm MPs particles demonstrated a 31.1% reduction in the mineralization rate. In high organic matter saline soil, the large-diameter MPs particles exhibited a capacity to mitigate the damage to soil aggregates to a certain extent and a notable increase in the DOC content. The DOC content demonstrated a first increase and then a subsequent decrease with the increase in concentration. With regard to the OCM rate, it can be observed that small-diameter MPs will increase the mineralization rate, while large-diameter MPs will decrease the mineralization rate. The results indicate that MPs can increase the microbial population of saline soil. The effect is more pronounced in larger particles. MPs can become a potential carbon source in the soil environment after entering the soil, but they cannot be immediately utilized. Therefore, MPs entering the soil can interfere with the measurement results when measuring organic carbon and other indicators in agricultural soil. Consequently, it is imperative to refine the methodology for quantifying organic matter in soil containing MPs, which can eliminate the confounding influence of the carbon content of MPs on the measurement outcomes.

Funding
The research is supported by: Cangzhou Natural Science Foundation (221001001D).

Authors Contributions
Authors have equally contributed in preparing the paper.

Availability of Data and Materials
The data are included in the article.

Conflict of Interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] L Lv, X Yan, L Feng, S Jiang, Z Lu, H Xie, and C Li. "Challenge for the detection of microplastics in the environment.". *Water Environment Research*, **93**(1): 5–15, 2021.

[2] B Li, W Liang, Q X Liu, S Fu, C Ma, Q Chen, and H Shi. "Fish ingest microplastics unintentionally.". *Environmental Science & Technology*, **55**(15):10471–10479, 2021.

[3] Y Wang, Y Liu, W Feng, and S Zeng. "Waste haven transfer and poverty-environment trap: evidence from EU.". *Green Low-Carbon Econ.*, **1**(1):41–49, 2023.

[4] S K Ahmed, W B Ali, and A A Khadom. "Synthesis and investigations of heterocyclic compounds as corrosion inhibitors for mild steel in hydrochloric acid.". *International Journal of Industrial Chemistry*, **10**(2): 159–173, 2019.

[5] A K Panda. "Thermo-catalytic degradation of different plastics to drop in liquid fuel using calcium bentonite catalyst.". *International Journal of Industrial Chemistry*, **9**(2):167–176, 2018.

[6] K Blackburn and D Green. "The potential effects of microplastics on human health: what is known and what is unknown.". *Ambio*, **51**(3):518–530, 2022.

[7] W Wang, H Zhang, N Vinay, D Wang, F Mo, and Y Liao et al. "Microbial functional genes within soil aggregates drive organic carbon mineralization under contrasting tillage practices.". *Land Degradation and Development*, **34**(12):3618–3635, 2023.

[8] H Zhang, Y Gao, Z Meng, B Chen, and L Huang. "Soil organic carbon mineralization after the addition of plant litter in Yinshanbeilu desert steppe under three utilization regimes.". *Polish Journal of Environmental Studies*, **31**(5):4469–4479, 2022.

[9] Q Zhang, Y Liu, Y Liu, H Liu, Z Zhang, Q Gao, and et al. "The contributions of soil biochemical characteristics and soil organic carbon (SOC) structure to SOC mineralization rate during forest succession on the Loess Plateau, China.". *Land Degradation and Development*, **33**(17):3375–3386, 2022.

[10] X Wei, T Ge, C Wu, S Wang, and Y Kuzyakov. "T4-like phages reveal the potential role of viruses in soil organic matter mineralization.". *Environmental Science & Technology*, **55**(9):6440–6448, 2021.

[11] X J Liu, S T Wang, L Mu, Y Y Xie, and X G Hu. "Microplastics reshape the fate of aqueous carbon by inducing dynamic changes in biodiversity and chemodiversity.". *Environmental Science & Technology*, **57** (28):10415–10425, 2023.

[12] K Xiao, L Song, Y Li, C Li, and S Zhang. "Dietary intake of microplastics impairs digestive performance, induces hepatic dysfunction, and shortens lifespan in the annual fishNothobranchius guentheri.". *Biogerontology*, **24**(2):176–183, 2023.

[13] Z Wang, K Lee, and Q Feng. "Overlooked role of bulk nanobubbles in the alteration and motion of microplastics in the ocean environment.". *Environmental Science & Technology*, **57**(30):11289–11299, 2023.

[14] J Wang, X Guo, and J Xue. "Biofilm-developed microplastics as vectors of pollutants in aquatic environments.". *Environmental Science & Technology*, **55** (19):12780–12790, 2021.

[15] Y Chen, K Sun, Y Yang, B Gao, and H Zheng. "Effects of biochar on the accumulation of necromass-derived carbon, the physical protection and microbial mineralization of soil organic carbon.". *Environmental Science & Technology*, **54**(1):39–67, 2024.

[16] Y Fu, Y Luo, M Auwal, B P Singh, L Van Zwieten, and J Xu. "Biochar accelerates soil organic carbon mineralization via rhizodeposit-activated actinobacteria.". *Biology and Fertility of Soils*, **58**(5):565–577, 2022.

[17] Z R Kan, W X Liu, W S Liu, R Lal, Y P Dang, X Zhao, and H L Zhang. "Mechanisms of soil organic carbon stability and its response to no-till: a global synthesis and perspective.". *Global Change Biology*, **28**(3):693–710, 2022.

[18] H Soinne, R Keskinen, M Räty, S Kanerva, E Turtola, J Kaseva, and T Salo. "Soil organic carbon and clay content as deciding factors for net nitrogen mineralization and cereal yields in boreal mineral soils.". *European Journal of Soil Science*, **72**(4):1497–1512, 2021.

[19] F Levavasseur, G Lashermes, B Mary, T Morvan, B Nicolardot, V Parnaudeau, and S Houot. "Quantifying and simulating carbon and nitrogen mineralization from diverse exogenous organic matters.". *Soil Use and Management*, **38**(1):21098–21104, 2022.

[20] C Wu, B Yan, H Jing, J Wang, X Gao, Y Liu, and G Wang. "Application of organic and chemical fertilizers promoted the accumulation of soil organic carbon in farmland on the Loess Plateau.". *Plant and Soil*, **483**(1):285–299, 2023.

[21] M Chen, S Zhang, L Liu, J Liu, and X Ding. "Organic fertilization increased soil organic carbon stability and sequestration by improving aggregate stability and iron oxide transformation in saline-alkaline soil.". *Plant and Soil*, **474**(2):233–249, 2022.

[22] M N Ashraf, G Jusheng, W Lei, A Mustafa, A Waqas, T Aziz, and X Minggang. "Soil microbial biomass and extracellular enzyme–mediated mineralization potentials of carbon and nitrogen under long-term fertilization (> 30 years) in a rice–rice cropping system.". *Journal of Soils and Sediments*, **21**(12):3789–3800, 2021.