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Microplastic Impacts on Greenhouse Gases Emissions in Terrestrial Ecosystems

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Abstract

Microplastics can influence global climate change by regulating the emissions of greenhouse gases from different ecosystems. The effects of microplastics in terrestrial ecosystems are still not well studied particularly greenhouse gases emissions. Thus, we conducted a laboratory experiment over a period of 90 days with two types of microplastics (differing in their chemical structure), high density polyethylene (HDPE) and low density polyethylene (LDPE), which were applied to the soil at a rate of 0% to 0.1% (w/w). The overarching aim was to investigate the effects of microplastic type, microplastic concentration and days of exposure on greenhouse gases emissions. We also used original and artificially weathered microplastics (the same HDPE and LDPE) to make a comparison of greenhouse gases emissions between the original microplastics treated soils and the soils treated with weathered microplastics. Our findings showed that HDPE and LDPE microplastics significantly increased the emissions of greenhouse gases from the soil than that of the control soils. Emissions were increased with the increases in the level of microplastic in the soil. The weathered microplastic emitted greater quantity of greenhouse gases compared to that of the original microplastics. In contrast to a low initial emission quantity, the emissions were gradually increased at the termination of the experiment. Our experiment on the emissions of greenhouse gases from the soil *vis-à-vis* microplastic additions indicated that the microplastic increased the emissions of greenhouse gases in terrestrial ecosystems, and pervasive microplastic impacts may have consequences for the global climate change. Greenhouse gases emissions from the soil not only depend on the type and concentration of the microplastic, but also on the days of exposure to the microplastic.

Keywords

Microplastic, Climate Change, Greenhouse Gas, Type, Concentration

1. Introduction

Climate change is one of the most important burning questions of the today's world. Climate change affects all kinds of ecosystems at multiple levels. Researchers found four key impacts of climate change: 1) Changes in species and populations; 2) Changes in the timing of natural events and cycles; 3) Changes in ecosystem interactions; 4) Altered/reduced ecosystem services [1]. According to Cox *et al.* [2], fossil fuels—coal, oil and gas, are by far the largest contributor to global climate change, accounting for over 75% of global greenhouse gas emissions and approximately 90% of all carbon dioxide (CO_2) emissions. Other factors of climate change include power generation, industry, disruption of forest ecosystems, excessive consumption of power, production and use of chemical fertilizers for enhancing crop productivity and combustion of petroleum-based products. Not only the anthropogenic activities are responsible for climate change but climate change can be attributed to natural phenomena also. Volcanic eruptions, fluctuations in solar radiation, tectonic shifts, and changes in earth's orbit have observable effects on planetary warming and cooling patterns leading to a shift in global climate [3] [4].

Carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), nitrogen oxides (NO_x) and volatile organic compounds (VOC_s) are important drivers of the anthropogenic greenhouse effects, which are released into the environment through various means [2] [3]. The sources of greenhouse gases emissions include electricity (31%), agricultural practices (11%), transportation (15%), burning of fossil and forestry (6%), as well as manufacturing (12%) [4]. Over time, the emissions have contributed to the overall effects of global warming. Every year the worldwide CO_2 emissions from energy needs increases, and by the year 2050 the global CO_2 emissions are forecast to increase to some 43.08 billion metric tons, in comparison to 35.30 billion metric tons of CO_2 in 2018 [5].

It is well documented that emission from the agricultural soils contributes to environmental and human health problems [2] [4]. The greenhouse gases emission from the soil to the atmosphere is the primary mechanism of nutrient loss from the soil [4] which in turn contributes to the global climate change. For example, emission of CO_2 plays a significant role in the loss of carbon from rural and agricultural soils. Terrestrial ecosystems that are now considered as net sinks for CO_2 might become net CO_2 sources after about 2050, if the projected temperature rise becomes a reality [6]. Agricultural intensification is associated with a number of carbon and nitrogen containing compounds, including nitric oxide, nitrous oxide, nitrogen dioxide, methane, carbon dioxide, carbon monoxide and volatile organic compounds, which are emitted to the atmosphere through agricultural operations [7].

Marine sediments, freshwater reservoirs and soils are important sources of greenhouse gases emissions [6] [8]. Most studies [9] [10] [11] to date mentioned the impacts of microplastics on the marine and freshwater ecosystems. However, the impacts of microplastics on the soil ecosystem is often overlooked due to the

complex, heterogenous nature of the soil [9] [11]. Compared with marine sediments, soils are basically in an aerobic environment and exchange materials with the atmosphere through the surrounding air. Thus, immediate attention should be paid to that whether microplastics will affect the soil ecological environment and greenhouse gases emissions. Current concerns about the impact of microplastics on soil ecosystems are mainly concentrated on soil properties [12], microbial diversity [13], and crop productivity [9] [10]. Few studies [14] [15] focused on the impacts of microplastics on greenhouse gases emissions although the findings varied depending on the shape and size of the microplastic, soil inherent characteristics (pH, texture, structure, moisture content, etc.) and plant species. The impact of the microplastics on the greenhouse gases emissions from the soil flux will help us to explore impacts on the biogeochemical cycles particularly carbon and nitrogen cycles.

The aims of the present experiment were therefore to determine: 1) The impacts of high density polyethylene (HDPE) microplastic on the emission of greenhouse gases from the soil; 2) The impacts of low density polyethylene (LDPE) microplastic on the emission of greenhouse gases from the soil; 3) Whether UV weathered microplastic emits more greenhouse gases than the original microplastic; 4) Whether different doses of microplastic and days of exposure have impacts on the greenhouse gases emissions from the soil flux.

2. Materials and Methods

2.1. Collection of Soil

Soil sample was collected from the top 20 cm from an arable field located at the University of Cambridge experimental farm (53˚12'17"N and 1˚6'48"E). The soils were Cambisols [16] and had silty loam texture. The bulk of soil samples were collected by composite soil sampling method and processed.

The soils were air-dried, visible roots and plant debris were discarded and the soils were ground gently to break up larger soil aggregates. After that the soils were sieved at 2 mm, thoroughly homogenized and finally characterized. Soil texture was determined manually [17]. The pH of the soil was determined by mixing air-dried soil and deionised water at a ratio of 1:2.5 followed by shaking for 15 minutes. The suspension was allowed to settle and pH was measured using an Accumet AB150 pH meter [18]. Soil organic matter was determined by heating 20 g of air-dried soil overnight at 105˚C, reweighed and then combusted at 350˚C overnight. Mass loss on ignition (LOI) was determined and used as a proxy for organic matter content [18] [19]. The pH of the soil was 6.72 and organic matter content was 3.15%.

2.2. Collection of Microplastics

High density polyethylene (HDPE) and low density polyethylene (LDPE) microplastics were purchased from Yuyao Zetuo Plastic Company Limited, located in Wuhan, China. The HDPE and LDPE microplastics were modified high-density

and low density polyethylene materials respectively having good balance of properties (Table 1). The size of the microplastics powder was approximately 300 μm that falls below 5 mm (maximum size for plastics to be considered microplastics) [20].

2.3. Generation of Weathered Microplastics

Two opaque, square shaped wooden boxes (height = 14 inch, length = 14 inch, width = 14 inch) were made to facilitate the weathering of microplastics. One wooden box was made for the HDPE microplastics and another one for the LDPE microplastics. An UV ozone generating light bulb (bulb base E17, input voltage AC100-240 V, wattage 3W, current 300 mA) having 185 nm wavelength was used inside the UV box. This approach mimicked the weathering of microplastics in the natural environment. A UV light bulb was purchased from TCP Company located in Pennsylvania, USA. The boxes were made opaque to protect the personnel from the harmful rays of UV. Original microplastics (not UV treated) were placed in the UV box to generate weathered microplastics. The microplastics were exposed to UV rays for 24 hours and took around 9 months to weather c. 15 g of microplastics. We differentiated the original and weathered microplastics by observing the differences in their spectra. We used the Fourier Transform Infrared Spectroscopy (FTIR) (model 530; spectral range 7800 - 350 cm^{-1}; signal to noise ratio 20,000:1) to determine the spectra. The phase resolution and phase interferogram points of the FTIR were 32 and 1880 respectively. High frequency limit was up to 8000 (16704.53 cm^{-1}) and laser wavenumber was 11600.37. Scanner velocity was set at 7.5 KHz. Finally the weathered HDPE and LDPE microplastics were collected from the UV box for further experimental use.

2.4. Measurement of Greenhouse Gases Emissions

A laboratory experiment was undertaken to investigate the comparative impacts of original and weathered microplastics on greenhouse gases emissions. This experiment was based on four groups of microplastic treatments *viz*., control, 0.01%, 0.1% and 1% (w/w) which were selected on the basis of values of microplastics found in natural environment. 0.01% microplastics is typically found in undisturbed soil whereas 1% is found in urban soil which is aggravated by different means [21]. All treatments were replicated five times. Each UV box contained

Table 1. Properties of HDPE and LDPE microplastics [20].

Properties	HDPE	LDPE
Processing method	Rotational molding	Rotational molding
Density	0.95 g/cm^3	0.61 g/cm^3
Bulk density	0.39 g/cm^3	0.14 g/cm^3
Melt mass-flow rate	7.8 g/min	7.1 g/min
Tensile strength at yield	22 Mpa	20 Mpa

c. 1000 g of moist soil. Microplastic was added to the soil according to the treatments. After adding the microplastics to the soil, the soils were thoroughly mixed to distribute the microplastics as evenly as possible. Water was added to the soil as required to keep the soil moist. We measured the greenhouses gases emissions every 5 days over a period of 90 days.

In the present experiment, the chamber method was chosen to measure the concentration of greenhouse gases emitted from the soil. We modified the method which was initially followed by [22]. An FTIR analyzer (GT5000 Terra-Splashproof multigas FTIR analyzer, Germany) was used to measure the gases accumulated within the chamber. FTIR worked by analyzing the entire infrared spectrum to measure all the infrared absorbing gases in the soil. Most molecules had a characteristic absorption spectrum that can be used to identify greenhouse gases and measure their concentrations. We used the chamber with a circulating loop and the gases were pumped from the chamber, passed through the analyzer and finally returned back to the chamber. The FTIR analyzer determined the concentrations of carbon dioxide (CO_2), carbon monoxide (CO), volatile organic compounds (VOC_s), methane (CH_4), nitric oxide (NO), nitrogen dioxide (NO_2) and nitrous oxide (N_2O).

2.5. Quality Control and Statistical Analysis

All data were analyzed using SigmaPlot (version 14) software. Data were tested for normal distribution using the Shapiro-Wilk and Kolmogorov-Smirnov test and equal variance using Levene's mean test. Data were log transformed which were not distributed normally. Analytical precision was calculated from the coefficient of variation (CV) determined from the duplicate analysis of 10% of the samples that were at least 100 times higher than the detection limit and determining the median of the difference between the duplicate measurements expressed as a percentage of their mean value [23]. Three-way analysis of variance (ANOVA) tests were used to detect the significant differences in the concentrations of various greenhouse gases emitted from the soil between the microplastic type (factor 1), microplastic treatment (factor 2) and day of exposure to the microplastic (factor 3).

3. Results and Discussion

3.1. Emission of Carbon Dioxide from the Soil

The effects of two different types of microplastics on the evolution of carbon dioxide (CO_2) were observed for over a period of 90 days (**Figure 1**). Data indicated that the concentration of CO_2 varied significantly ($p \leq 0.05$) with the microplastic type, treatment and day of exposure. Interactions of these three factors were also significant ($p \leq 0.05$). The weathered microplastics emitted a higher concentration of CO_2 than the original microplastics. It was applicable for both HDPE and LDPE microplastics. While comparing the mean CO_2 concentrations of HDPE and LDPE, HDPE showed higher emission of CO_2. Mean CO_2 concentration

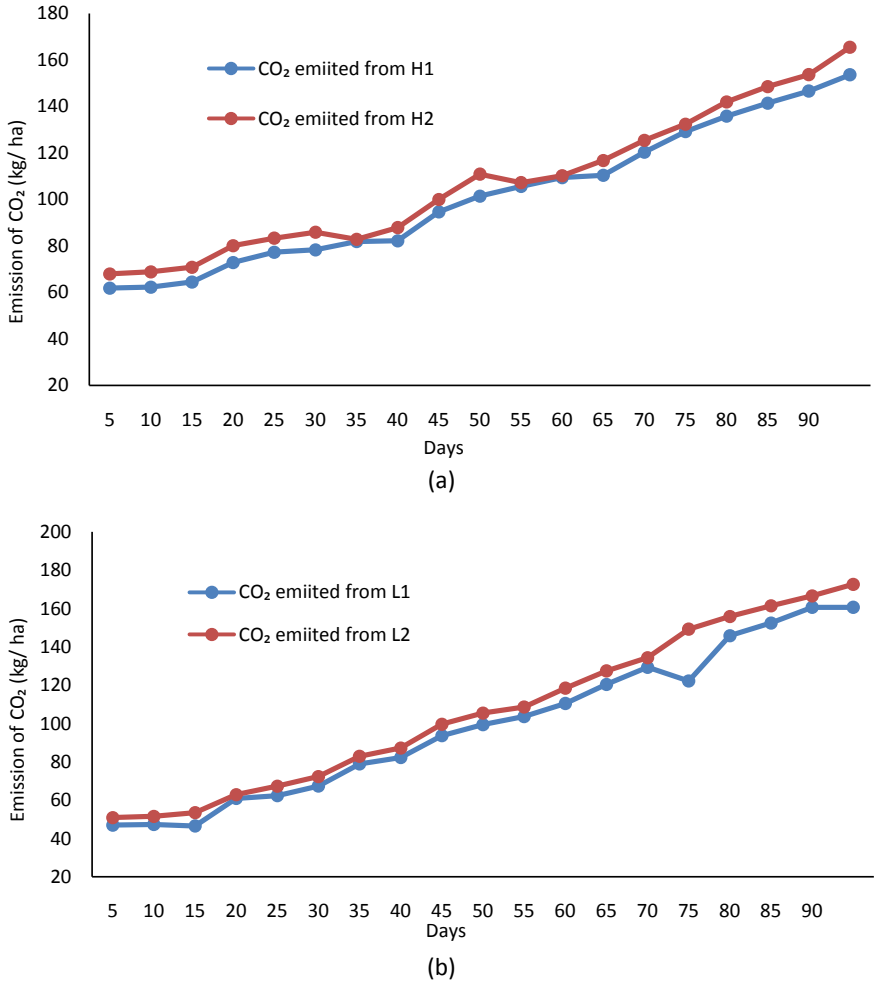

Figure 1. Emission of carbon dioxide from the soil. H1 = original HDPE microplastics, H2 = weathered HDPE microplastics, L1 = original LDPE microplastics and L2 = weathered HDPE microplastics.

was significantly lower in control soils (H1 = 61.89 kg/ha; H2 = 67.98 kg/ha; L1 = 47.01 kg/ha; L2 = 50.92 kg/ha) compared to that of the microplastic treated soils. Microplastic treatments of 0.01%, 0.1% and 1% differed significantly. Microplastic type and treatment showed significant ($p \leq 0.05$) interaction whilst the interaction between the treatment and day of exposure was not significant ($p > 0.05$) as indicated by the three-way ANOVA tests.

3.2. Emission of Carbon Monoxide from the Soil

Data of carbon monoxide (CO) showed that regardless of various applied treatments, both the HDPE and LDPE microplastics followed, though fluctuating, a resembling pattern (**Figure 2**). The CO emitted from the soil flux varied significantly ($p \leq 0.05$) with the microplastic type, treatment and day of exposure to the microplastic. However, interactions of these three factors were not significant ($p > 0.05$). Emission of CO was not significantly ($p > 0.05$) affected by the interaction between microplastic type and treatment whereas interaction between

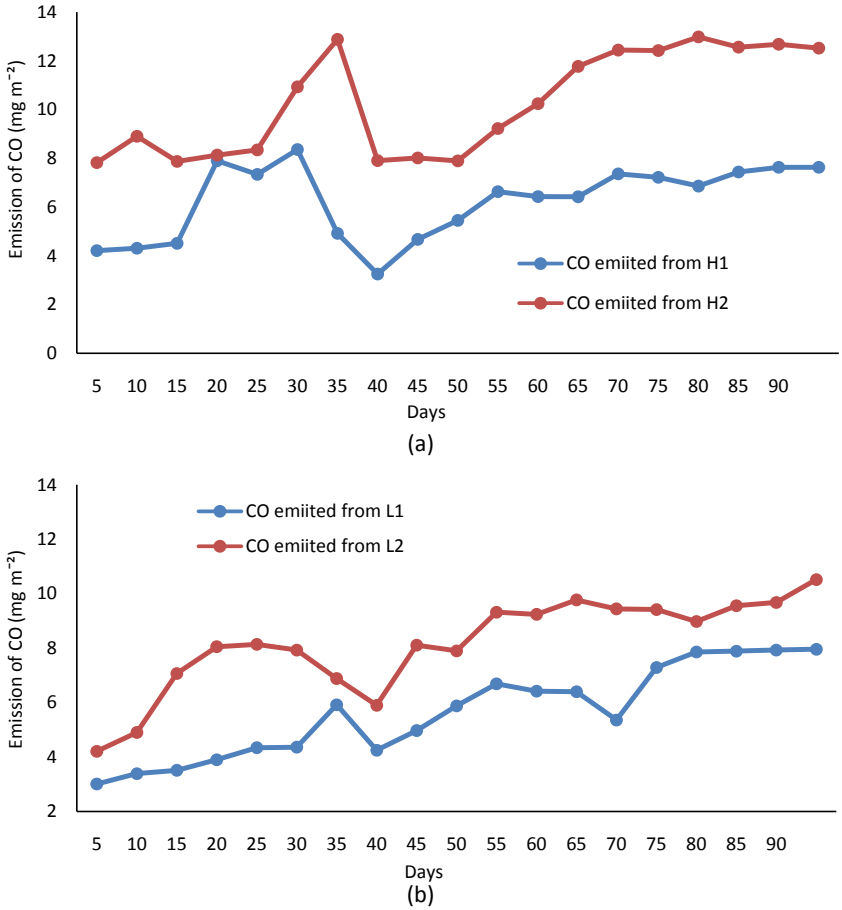

Figure 2. Emission of carbon monoxide from the soil. H1 = original HDPE microplastics, H2 = weathered HDPE microplastics, L1 = original LDPE microplastics and L2 = weathered HDPE microplastics.

microplastic type and day of exposure significantly ($p \leq 0.05$) impacted on the evolution of CO from the soil. The weathered HDPE and LDPE microplastics emitted a higher concentration of CO than the original microplastics. The mean emission of CO was higher from the HDPE compared to the LDPE. For the original, untreated HDPE and LDPE microplastics, control soils emitted lower CO compared to the microplastic treated soils which was increased between day 20 and day 35 followed by a sharp decrease at day 40. Carbon monoxide emission was then gradually increased up to day 90 which exceeded the emissions of the control soils (**Figure 2**). The weathered HDPE and LDPE microplastics followed the same trend as the untreated microplastics. Significant ($p \leq 0.05$) variations were observed between the microplastic treatments. Emission of CO was increased significantly with the increases in microplastic doses.

3.3. Emission of Volatile Organic Compounds from the Soil

There were significant ($p \leq 0.05$) differences in the evolution of volatile organic compounds (VOC_s) from the soil between the microplastic type, treatment and day of exposure. Interaction between the three factors was also highly signifi-

cant. Control soils emitted significantly ($p \leq 0.05$) lesser amount of VOC_s compared to that of the microplastics treated soils; both the HDPE and LDPE treated soils showed the similar trend. Comparing the emission of VOC_s from the original and weathered microplastics treated soils, initially the emission was less which was then increased to c. 900 (for original microplastics) and 1300 times (for weathered microplastics) in the terminal periods of the experiment (Figure 3). Across the days maximum emission was found for the day 90 whilst minimum emission for the day 1. There were no significant ($p > 0.5$) differences in VOC_s evolution between the day 45 and 50. However, significant ($p \leq 0.5$) differences were observed between the microplastic type and treatment, and between microplastic treatment and day of exposure.

3.4. Emission of Methane from the Soil

Emission of methane (CH_4) from the soil flux did not follow a definite pattern. The pattern was different from the emission of other greenhouse gases studied in the present experiment. There were significant ($p \leq 0.05$) differences found in

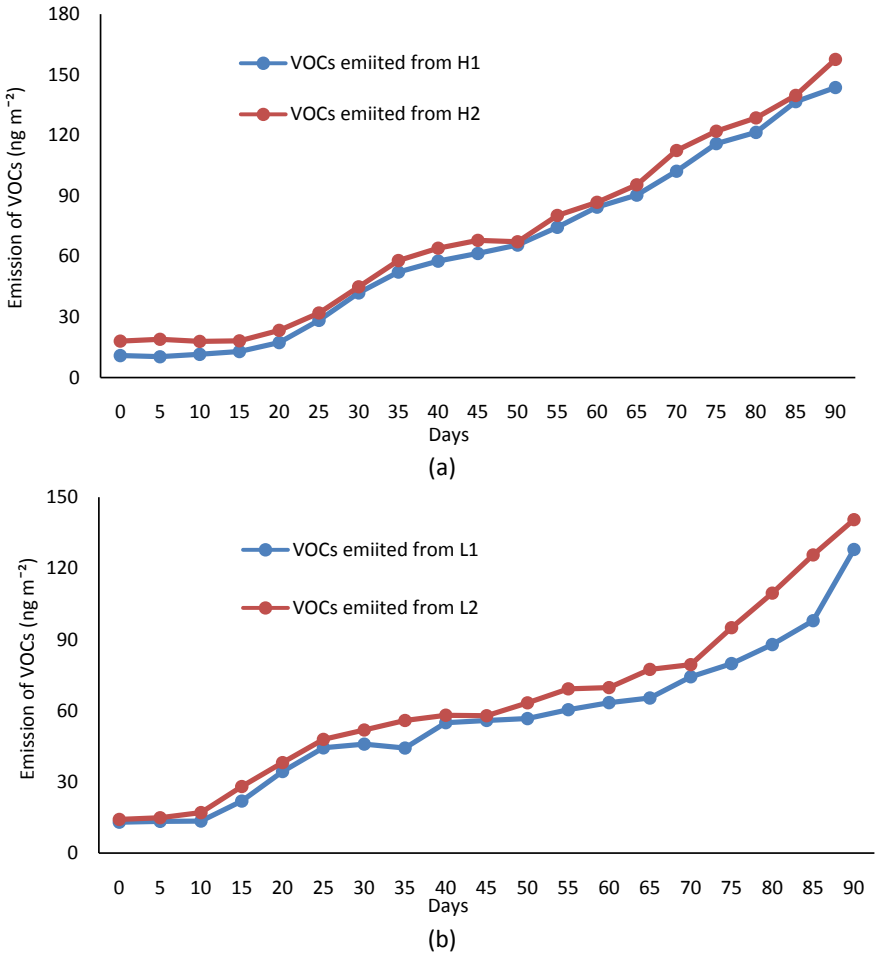

Figure 3. Emission of volatile organic compounds from the soil. H1 = original HDPE microplastics, H2 = weathered HDPE microplastics, L1 = original LDPE microplastics and L2 = weathered HDPE microplastics.

the emission of CH_4 between the microplastic type, treatment and day of exposure, although the interactions of these three factors were not significant ($p > 0.05$). The microplastic type and day of exposure showed significant interaction whilst the interaction between the treatment and day of exposure was not significant. The microplastic type and treatment showed significant interaction on the emission of CH_4. Initially the control soils emitted lesser amount of CH_4 which was decreased between day 45 and 70 followed by a sharp increase. The emission at day 90 was higher than the control values (Figure 4).

3.5. Emission of Nitrogen Oxides from the Soil

We determined the emission of three types of nitrogen oxides (NO_x) *viz.*, nitric oxide (NO), nitrogen dioxide (NO_2) and nitrous oxide (N_2O). Microplastic type, treatment and day of exposure showed significant ($p \leq 0.05$) variations on the emissions of NO, NO_2 and N_2O. For the NO, microplastic type and treatment showed significant ($p \leq 0.05$) variations whereas microplastic treatment and day of exposure showed no significant ($p > 0.05$) variations. For the NO_2, microplastic type and day of exposure showed significant ($p \leq 0.05$) differences whereas

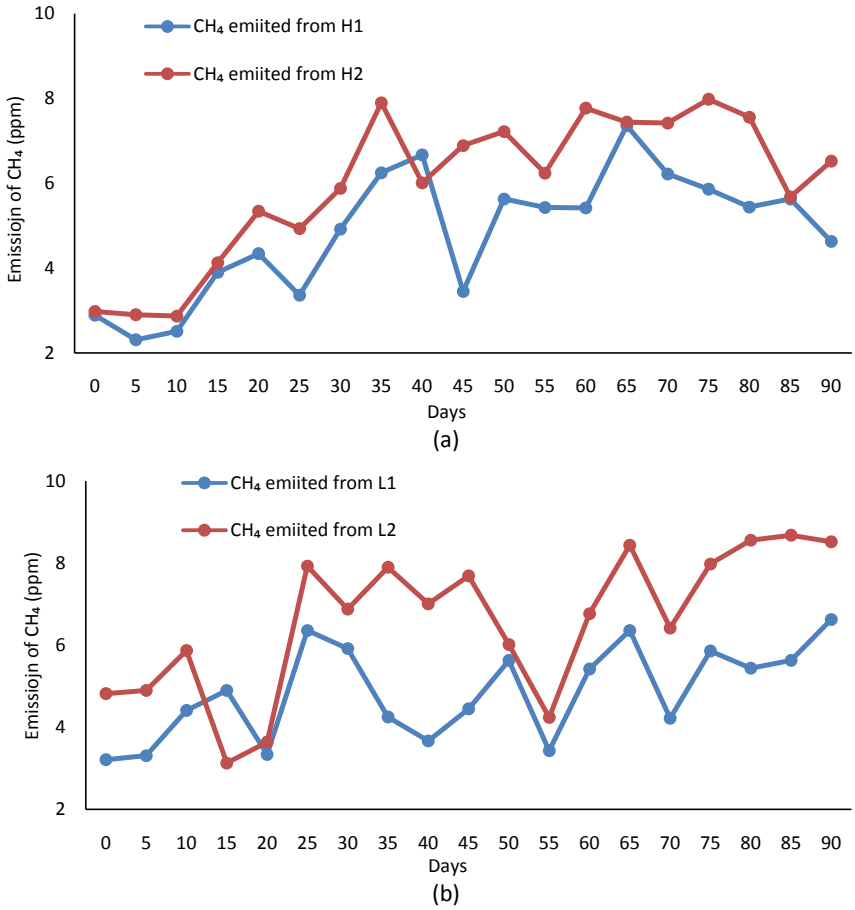

Figure 4. Emission of methane from the soil. H1 = original HDPE microplastics, H2 = weathered HDPE microplastics, L1 = original LDPE microplastics and L2 = weathered HDPE microplastics.

microplastic treatment and day of exposure showed no significant ($p > 0.05$) differences. For the N_2O, non-significant ($p > 0.05$) differences were found between microplastic type and treatment, between microplastic treatment and day of exposure, and between microplastic type and day of exposure. However, interaction between all the three factors was found to be significant. Emission of NO_x was lower at day 1 which was increased with exposure time. Emission from the HDPE was increased about 40%, 52% and 32% for the NO, NO_2 and N_2O respectively (Table 2, Table 3). Emission from the LDPE was increased about 34%, 48% and 25% for the NO, NO_2 and N_2O respectively (Table 2, Table 3).

4. Discussion

Our data indicated that the emissions of various greenhouse gases (CO_2, CO, VOC_s, CH_4, NO, NO_2 and N_2O (Figures 1-4; Table 2, Table 3) from the soil flux

Table 2. Emission of nitrogen oxides from the soil in presence of HDPE. H1 = original HDPE microplastics and H2 = weathered HDPE microplastics. Nitrogen oxides were nitric oxide (NO), nitrogen dioxide (NO_2) and nitrous oxide (N_2O).

Days	Emission from H1 (ppm)	Emission from H2 (ppm)	Emission from H1 (ppm)	Emission from H2 (ppm)	Emission from H1 (ppm)	Emission from H2 (ppm)
	NO		N_2O		NO_2	
0	0.73	0.76	0.42	0.46	1.05	1.11
5	0.75	0.79	0.41	0.47	1.07	1.15
10	0.76	0.79	0.45	0.47	1.06	1.15
15	0.76	0.78	0.48	0.51	1.07	1.17
20	0.77	0.81	0.46	0.51	1.06	1.19
25	0.8	0.81	0.51	0.53	1.14	1.19
30	0.79	0.84	0.52	0.56	1.11	1.34
35	0.82	0.85	0.56	0.58	1.09	1.23
40	0.85	0.88	0.59	0.62	1.16	1.32
45	0.88	0.9	0.63	0.67	1.19	1.33
50	0.88	0.9	0.61	0.69	1.18	1.45
55	0.89	0.92	0.59	0.72	1.13	1.44
60	0.92	0.91	0.62	0.76	1.15	1.46
65	0.94	0.94	0.66	0.8	1.16	1.47
70	0.97	0.98	0.68	0.79	1.16	1.42
75	1.01	1.05	0.67	0.78	1.14	1.41
80	0.98	1.04	0.68	0.82	1.16	1.43
85	1.02	1.14	0.67	0.81	1.17	1.44
90	1.02	1.13	0.72	0.82	1.15	1.46

Table 3. Emission of nitrogen oxides from the soil in presence of LDPE. L1 = original LDPE microplastics and L2 = weathered LDPE microplastics. Nitrogen oxides were nitric oxide (NO), nitrogen dioxide (NO_2) and nitrous oxide (N_2O).

Days	Emission from L1 (ppm)	Emission from L2 (ppm)	Emission from L1 (ppm)	Emission from L2 (ppm)	Emission from L1 (ppm)	Emission from L2 (ppm)
	NO		N_2O		NO_2	
0	0.53	0.66	0.56	0.66	1.02	1.21
5	0.55	0.69	0.51	0.67	1.02	1.25
10	0.59	0.69	0.55	0.67	1.08	1.25
15	0.56	0.68	0.51	0.61	1.09	1.27
20	0.67	0.67	0.55	0.71	1.03	1.56
25	0.68	0.71	0.51	0.63	1.08	1.59
30	0.69	0.74	0.55	0.66	1.09	1.54
35	0.62	0.65	0.66	0.78	1.03	1.63
40	0.65	0.78	0.69	0.72	1.12	1.62
45	0.68	0.79	0.73	0.77	1.14	1.23
50	0.72	0.79	0.71	0.79	1.21	1.55
55	0.79	0.82	0.79	0.82	1.22	1.54
60	0.72	0.81	0.82	0.86	1.25	1.56
65	0.74	0.84	0.86	0.92	1.18	1.57
70	0.77	0.88	0.82	0.99	1.14	1.52
75	0.71	0.95	0.86	0.98	1.17	1.61
80	0.78	0.94	0.88	0.92	1.26	1.63
85	0.72	0.92	0.87	0.91	1.27	1.74
90	0.73	0.94	0.82	0.92	1.25	1.76

were significantly affected by the microplastic treatments. Emissions were increased with the increases in microplastic treatments which were consistent with previous studies [11] [24] although the authors used different type of microplastics. Emission of CO_2 (**Figure 1**) is linked to microbial respiration; higher emission could be due to higher microbial respiration in the soil. Microplastic contains carbon (typically around 80%) and the carbon acts as a food source for the soil microbes [9]. The microplastics could feed the soil microbes causing a priming effect which led to increased microbial activity with potential increases in microbial respiration leading to the higher emission of CO_2 from the soil. Higher emissions of greenhouse gases with the application of high levels of microplastic treatments as suggested by [10] [25] was the leaching of additives and monomers (atoms/molecules that bond together to form polymer) that could provide a food source for the soil microbes.

[26] observed increased respiration with the increases in microplastic doses

which supported our findings. Weathered microplastics treated soils had higher emissions of greenhouse gases compared to that of the soils treated with the original form of microplastics which might be due to the increased surface area of the weathered microplastics. By increasing the surface area, chemical processes acted more easily upon the microplastic surface [27]. [28] and [29] observed increased adsorption of metals by the UV weathered microplastics. They suggested that that the increased adsorption was due to the increases in surface area and greater heterogeneity [29].

The increases in the emissions of CH_4 and NO_x (**Figure 4**; **Table 2**, **Table 3**) from the microplastic treated soils were not in line with previous literatures [7] [10] [24]. However, the authors conducted their experiments in marine sediments where ocean currents, marine plants and marine microbes played a significant role in the emission of greenhouse gases from the sediment. The physiology of marine plant and microbes are completely different from the terrestrial ones. UV weathering is also pronounced in the marine environments rather than the terrestrial ecosystems [30]. Microplastics could affect microbial community while entering the marine sediment leading to a change in the ecological environment. This could, in turn, lead to a change in the emissions of greenhouse gases and ultimately changes on the global climate. Authors [24] mentioned that the presence of polyethylene terephthalate microplastics reduced the bacterial diversity in paddy soils which resulted in a reduction of cumulative CH_4 emissions by 53%. Polyethylene (PE) microplastics in fertilized soils reduced the global warming by 2% by decreasing N_2O emissions. However, this PE microplastics accelerated the formation of aromatic functional groups which had a detrimental effect on microorganisms [15]. Presence of LDPE microplastics reduced the emissions of CO_2 and N_2O along with the microbial biomass carbon content in the soil [31]. Microplastics significantly affected NO_x emissions by affecting microbial diversity and community structure related to inorganic nitrogen content in overlying water. Studies showed that microplastics increased activities of oxidizing bacteria (e.g. *Betaproteobacteria*, *Gammaproteobacteria* and *Proteobacteria*) which resulted in increased microbial biomass [32]. These findings supported our present study. *Betaproteobacteria* and *Gammaproteobacteria* can oxidize ammonia (NH_4^+) to nitrate (NO_2) whereas *Proteobacteria* have the ability to reduce NO_2 to nitric oxide (NO). Thus, the emissions of NO_2 and NO gases from the soil were significantly higher from the microplastic treated soils (**Table 2**, **Table 3**).

The addition of microplastics affected both nitrification and denitrification processes at different times in freshwater sediments [15]. With the increase of exposure time of microplastics, the denitrification was gradually enhanced, followed by an increased content of N_2O. Thus the presence of microplastics could affect nitrogen cycle in freshwater sediment by emissions of NO_x. However, due to different particle sizes, the peak values of N_2O and NO in water measured in various treatment groups were different. It becomes imperative to determine the peak and timing of the effects of microplastics with different particle sizes in the

long-term exposure experiment.

Carbon monoxide (CO) is produced from the decomposition of organic matters present in the soil. The microplastics could enhance the activity of decomposing microbes in the soil which facilitated the decomposition of organic matters leading to the higher emissions of CO. Studies [24] [32] hypothesized that the application of microplastics to soils resulted in greater soil carbon sequestration potential that would reduce CO emission which contradicted our study. It is well documented that the microplastics have cracks on their surfaces [33] which might enable a wide range of volatile organic compounds (VOC_s) to be retained in the cracks of microplastics. This was in agreement with our present observations; we found comparatively higher emissions of VOC_s from the microplastic treated soils than the controls.

Global climate change is not a future problem; it is affecting our world at present. Changes to the earth's climate driven by increased emissions of heat-trapping greenhouse gases are already having widespread effects on the environment, and consequently glaciers are shrinking, river and lake ice sheets are breaking up earlier, geographic ranges of plants and animals are shifting, as well as plants are blooming sooner. The Intergovernmental Panel on Climate Change (IPCC) [34] stated that "the magnitude and rate of climate change and associated risks depend strongly on near-term mitigation and adaptation actions, and projected adverse impacts and related losses and damages escalate with every increment of global warming". Cheng [35] and Yadvinder [36] mentioned that "the scientific evidence is unequivocal; climate change is a threat to human wellbeing and the health of the planet".

At present, some changes in our global climate (such as droughts, wildfires, and extreme rainfall) are happening faster than scientists previously assessed [35] [36] [37]. According to the report of IPCC [34], human emissions of heat-trapping gases have already warmed the climate by nearly 2˚F (1.1˚C) since 1850-1900. The global average temperature is expected to reach or exceed 1.5˚C (about 3˚F) within the next few decades. These changes will affect all regions of Earth. The magnitude of climate change effects will depend on the human activities [37]. More greenhouse gas emissions will lead to more climate extremes and widespread damaging effects across our planet [38] [39].

5. Conclusion

This study examined how the microplastics impact on greenhouse gases emissions from the soil, and whether these impacts were varied depending on the microplastic type, microplastic concentration and days of exposure. The experiment was designed with two types of microplastics (HDPE and LDPE) and four levels of microplastic treatments (0%, 0.01%, 0.1% and 1.0%). We also used original (untreated) and weathered microplastics (UV treated) of the same HDPE and LDPE to investigate the impacts of original and weathered microplastics on the emissions of greenhouse gases. This study showed that both HDPE and LDPE

microplastics significantly increased the emissions of greenhouse gases from the soil than that of the control soils. The higher the concentration of microplastic, the greater was the emission of greenhouse gas. The weathered microplastic emitted greater quantity of gases compared to that of the original microplastics which could be due to the higher surface area and increased heterogeneity of the weathered microplastic. In contrast to a low initial emission quantity, the emissions were gradually increased at the termination of the experiment. Given the higher emission quantities of greenhouse gases from the soil flux due to the presence of microplastics in soil it seems likely to impact global climate change. A more detailed investigation into the greenhouse gases emissions would be required coupled with climatic parameters (temperature, precipitation, relative humidity, etc.) to cast further light on this. The natural progression for future work from this experiment would be field scale studies that would aim to understand how the microplastic alters the greenhouse gases emissions in the natural environment. Overall our results showed that microplastic impacts had consequences for greenhouse gases emissions in the terrestrial ecosystems. These impacts depend on the type and concentration of the microplastic as well as the days of exposure to the microplastic.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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