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EFFECTS OF DIFFERENT SOURCES OF BIOCHAR APPLICATION ON THE EMISSION OF A NUMBER OF GASES FROM SOIL

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ABSTRACT

Addition of biochar to soils has the potentials to reduce the emission of greenhouse gases from soil. The primary objectives of this study were to see the impacts of biochar and the corresponding biomass application on the emission of carbon dioxide (CO_2), carbon monoxide (CO), phosphine (PH_3) and volatile organic compounds (VOCs) from soil investigated in a closed container experiment. Three replications of seven different treatments were applied: i) soil only (control), soil incorporated with - ii) rice husk, iii) biochar produced from rice husk, iv) straw, v) biochar from straw, vi) saw dust and vii) biochar produced from saw dust. The study reveals that addition of biochar had significant effects ($P<0.05$) on reducing CO_2 and PH_3 emission while no statistically significant effects on VOCs emanation was evident. Application of biochar could not suppress the CO emissions. Our study indicates that, different types of biochars have different effects on the emission of different gases.

Keywords: Biochar, gas emission, soil health.

INTRODUCTION

Climate change is one of the most important challenges facing the modern world. Carbon dioxide (CO_2), methane (CH_4) and nitrogen oxides (NO_x) are important drivers of the anthropogenic greenhouse effect, which are released both through burning of fossil and biomass fuel as well as decomposition of above and below-ground organic matter. Over time, these emissions have contributed to the overall effects of global warming. Every year the world wide carbon dioxide (CO_2) emissions from energy needs increases, and by the year 2020 the world will produce 33.8 billion metric tons up from 29.7 billion metric tons in 2007 (US Energy Information Administration, 2010).

A growing body of evidence suggests that agricultural emissions contribute to environmental and human health problems. The Carbon dioxide emission from the soil to the atmosphere is the primary mechanism of carbon loss from the soil (Parkin and Kaspar, 2003) which in turn contribute to the global greenhouse gas emission. Forest ecosystems that are now net sinks for CO_2 might become net sources after about 2050, if the projected temperature rise becomes a reality (Cox *et al*., 2000). Agricultural intensification comes with a downside: a number of nitrogen-sulfur- and carbon-containing compounds, including ammonia, nitrogen oxides, nitrous oxide, hydrogen sulfide, methane, carbon dioxide and volatile organic compounds are emitted through agricultural operations (Aneja *et al.,* 2006). Some agricultural air pollutants (for example, ammonia, hydrogen sulfide, toxic organic compounds, pesticides, insecticides, and particulate matter) can affect human health as well as the comfort, health and production efficiency of animals (Donham *et al.,* 1982). According to some schools of thought, applying biochar into the soil to sequester carbon as well as to limit the emission of nitrogenous gases from soil is a realistic platform. The emergence of biochar, from the pyrolysis of biomass, as a carbon sink is not new and has been proposed before (Seifritz, 1993) but was not explicitly linked to an application to soil. The introduction of biochar (charcoal or carbon derived from biomass via pyrolysis) to the soil produces a long-term carbon sink in terrestrial ecosystems (Lehmann *et al*., 2006). Biochar slows down the decaying and mineralization of the biological carbon cycle to establish a carbon sink and a net carbon withdrawal from the atmosphere. Additionally calculations have shown that putting this biochar back into the soil can reduce emissions by 12-84 percent of current values; a positive form of sequestration that offers the chance to turn bio-energy into a carbon negative industry (Lehmann, 2007).

Albeit the promising prospect of biochar utilization, with some observations reporting negative consequences on soil and crop production along with the high initial energy consumption during the manufacturing of biochar, (Laird *et al*., 2008) however, the specific objectives of this study were to examine: (1) the comparative effectiveness of biochar and biomass application in suppressing the emission of carbon dioxide (CO_2), carbon monoxide (CO), phosphine (PH_3) and volatile organic compounds (VOCs) from soil and (2) the comparative effectiveness of the biochars of different provenances.

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MATERIALS AND METHODS

Biochar production

Biochar was produced from the raw materials of disparate sources; rice husk, straw and saw dust, employing the process of slow pyrolysis. A large hollow earthen pot was filled with dry wooden chips (smeared with some diesel) and the opening end of the pot was covered with an iron net of considerable resilience to withstand high temperature. Four small earthen pots, filled with biomasses and made impregnable to air penetration, were placed upon the iron net. Wooden chips were kindled and the pyrolysis initiated. Forty five minutes later, the fire was put off and after considerable cooling period the small pots were inspected to confirm the biochar production. This system can be termed as open fire system.

The produced biochar were then subjected to further processing. The biochar particles were passed through a set of sieve of 2 to 0.2mm. Biochar samples were preserved in plastic containers. Labeling of the produced biochars was as follows:

1. Rice Husk-Biochar: BC-1,
2. Straw- Biochar: BC-2, and
3. Saw Dust- Biochar: BC-3

Biochar can be produced from different types of organic feedstock but for this study biomasses were collected from different corners of Bangladesh. For instance, rice husk was collected from a rice mill, straw from a rice field and saw dust from (mango wood) from a saw mill.

Biomasses were excised into small pieces only in case of straw and then were flailed in a grinder machine. Ground samples were screened through a 0.2mm stainless still sieve. The sieved samples were then mixed thoroughly for making a composite sample. Biomass samples were preserved in plastic containers. The labeling of the biomasses was as follows:

1. Rice Husk-Biomass: BM-1
2. Straw-Biomass: BM-2 and
3. Saw Dust-Biomass: BM-3

Soil sample collection

Soil samples were collected from a depth of 0-15cm by composite soil sampling method as suggested by Imamul Huq and Alam (2005) from Manikganj Sadar upazila, Manikganj, Bangladesh (51°.884 N and 90°06.219 E). The soils thus collected belong to the Young Brahmaputra Floodplain representing the Melandaha series (Fig. 1). The soil texture is silt loam (sand: 13.9%, silt: 74.1%,

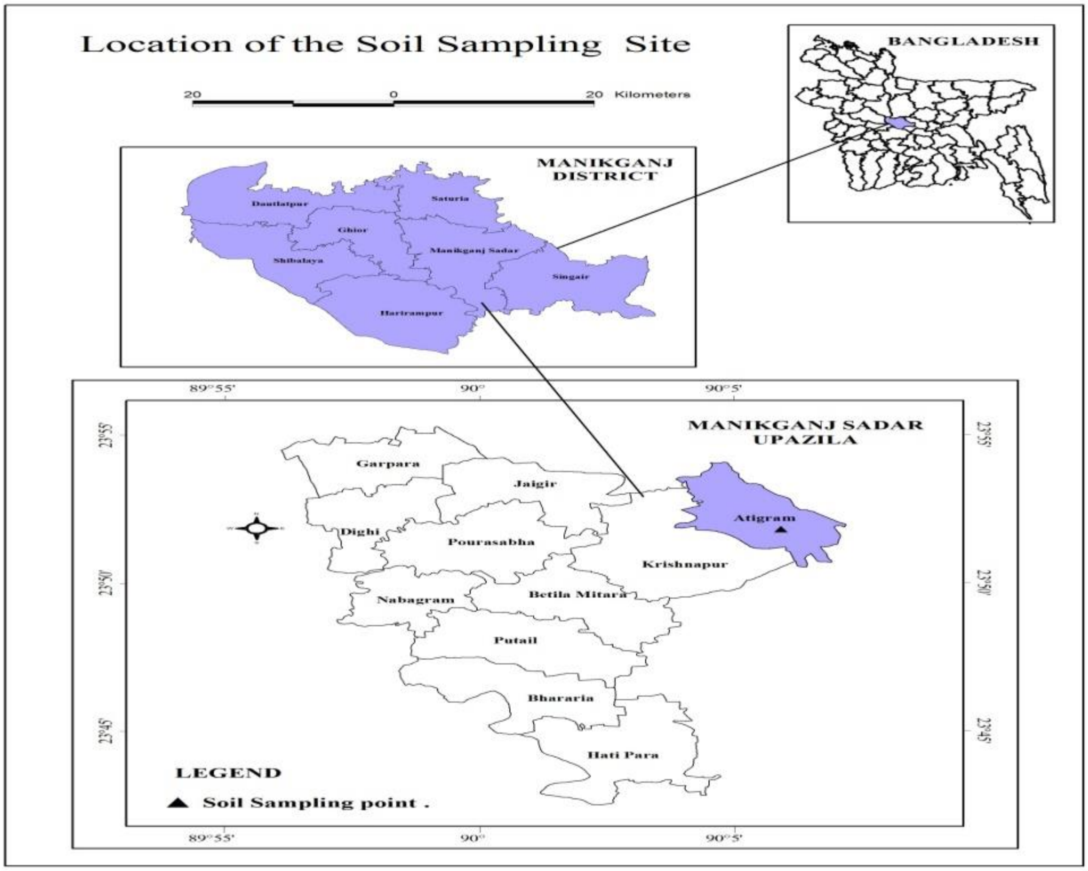

Fig. 1. The GPS-GIS based location map of the soil sampling site.

clay: 12.0%). The Melandaha series consists of intermittently or seasonally very shallowly flooded, imperfectly to poorly drained, very weakly developed medium textured soil. They have grey to olive grey, finely mottled, usually structure less, very fine sandy loam to silt loam below top soil. They are near neutral in reaction. The soil is Aeric Haplaquepts (Imamul Huq and Shoaib, 2013).

The collected soil samples were dried in air for 3 days (at ~40°C), freed from visible roots and debris. To expedite the drying process, the soil samples were exposed to sunlight and a consequent hammering (with a wooden hammer) to get rid of massive aggregates. Ground samples were screened through a 5mm stainless still sieve. The sieved samples were then mixed thoroughly for making a composite sample. Soil samples were preserved in plastic containers.

The experimental setup

For detecting and measuring the emissions of different gases, plastic containers of 5 liter capacities were procured from the local market. A total of 21 containers were used and each received a special modification treatment for capturing evolved gases. At first, the containers were washed properly with distilled water and dried in sunlight and stored. The containers were made completely air tight thus had no leaks in them. Two vents were made deliberately on each of the containers for two different purposes. The first one was made on the top of the lid in order to make a passage for inserting the probes which detected and measured evolved gases. The other one was made on the sides of each container to insert a canola for application of water during the incubation period. Plastic funnels were used to hold water and a 9 inches rubber tube acted as conduit between the funnel and the canola. A small piece of bamboo stick was tied to each container to hold the funnel on top of the whole system. Each funnel was wrapped with cotton and aluminum foil for proper concealment (Fig. 2). The foil and cotton were only removed when it was time to apply water to the system. A 2.5kg of the 5mm sieved soil was used for each pot. The sieved soil was mixed with biomass and biochar at the rate of 5ton/hectare (each pot with 2.5kg of soil received 5gm of biochar or biomass). All treatments were in triplicates. Volume inside each container after filling them with soil was 3.3liter. Surface area of the soil inside the container was calculated by the "πr^2" formula as the shape of the container was round. Impacts of the biochars as well as of the corresponding biomasses on the greenhouse gas emission from soil were observed over a period of 60 days. In the first month of incubation, observations were made on every alternate day. In the second month, observations were made every week for 4 consecutive weeks. The designs of the experiments are shown in table 1.

Table 1. Design of the container arrangement.

Treatment No.	Treatments	Symbols
1-3	Control soil (only soil)	C
4-6	Soil + Rice husk (Biomass)	BM-1
7-9	Soil + Rice straw(Biomass)	BM-2
10- 12	Soil + Saw dust (Biomass)	BM-3
13-15	Soil + Rice straw (Biochar)	BC-1
16-18	Soil + Rice husk (Biochar)	BC-2
19-21	Soil + Saw dust (Biochar)	BC-3

Detection and measurement of greenhouse gases

For the determination of CO_2 and CH_4 a portable CO_2 meter manufactured by Columbus Instruments was used. The results shown by this instrument is in percentage of the volume of air in the container. On the other hand, NO, PH_3, H_2S, VOCs, CO and NH_3 were detected and measured by an Indoor Air Quality monitor kit manufactured by Wolf stream which gave the data on parts per million basis.

The amount of gas emitted was converted to Kg/ha or gm/ha as follows:

For CO_2 (lit/ha) = (amount in ml × 10,000) / (surface area of the soil in the container ×1000)

As per law: $V_1/T_1 = V_2/T_2$

Here,

V_1 = Volume of the CO_2 in the container; T_1 = Temperature of the observation day; V_2 = Volume of gas at S.T.P. And T_2 = Standard temperature = 293 K

So volume of CO_2 in the container = $(V_2 \times T_2) / T_1$

Again, we know, $\rho = m \times v$

Where,

ρ = Density of CO_2 at standard temperature and pressure; v = Volume of CO_2 determined at standard temperature and pressure and m = Mass of CO_2

Now, $m = (\rho \times V_1)$ Kg/ha of CO_2.

For the gases other than CO_2, observed values in parts per million (ppm) were converted into percentage and then calculated as above.

Statistical analysis

All the data in the present experiment were statistically analyzed by using Microsoft Excel and/or MINITAB (version 16) Packages.

Fig. 2. Containers to capture evolved gases.

RESULTS AND DISCUSSION

Impact of Biochar and Biomass on the Evolution of Carbon Dioxide from Soil

The effects of biochar and biomass on the evolution of carbon dioxide (kg/ha) as affected by the various sources of biomasses and biochars were observed for over a period of 60 days. The gas evolved is expressed as kg ha^{-1} and the results are presented in the table 2 and the pattern of CO_2 evolution is graphically presented in the figures 3 (a, b, c).

The average emission of carbon dioxide from control soil (63.1kg/ha) is considerably lower compared to all the biomass treated soils (Table 2). Soils treated with biochars indicate higher average emission of carbon dioxide than the control soils, except for rice husk biochar treated soil (Table 2). While comparing the average carbon dioxide emission from biochar treated soils with their corresponding biomass counterparts, saw dust biochar application showed higher average values (87.6 kg/ha) while the remaining other two stated the opposite (Table 2).

Table 2 and the figures 3 (a, b, c) show the emission trends over 60 days of all the treatments and reveal somewhat resemblances in emission trends among each other except for saw dust treatment (both biomass and biochar). Throughout the entire experiment, the emission of carbon dioxide from BM-1 and BM-2 soils show increasing trends compared to BC-1 and BC-2 soils which exhibit a continuous declining trend (Fig. 3 a and b). The average carbon dioxide emissions from BM-1 and BM-2 soils were 98.2 kg/ha and 99.0 kg/ha, respectively, and are significantly higher compared to the average emissions from BC-1 and BC-2 soils (59.5 kg/ha and 71.1 kg/ha, respectively) (Table 2). The validation of these empirical data yielded significant results (P value 0.00) at

Table 2. Quantities of carbon dioxide (kg ha^{-1}) emitted from differently treated soils.

Day	Control	BM-1	BC-1	BM-2	BC-2	BM-3	BC-3
1	83.3	86.5	107.5	87.8	114.9	144.5	265.7
3	51.4	85.9	80.0	91	112.6	123.5	216.3
5	62.0	91.5	83.0	96.8	107.2	95.7	186.1
7	52.8	92.9	79.2	117.9	99.2	85.5	148.8
9	54.9	100.4	76.1	109.7	94	80.3	136.3
11	59.0	178	77.9	131	93.7	67.4	107.4
13	55.6	136.4	76.6	119.2	88.1	71.3	88.1
15	58.1	118.3	67.6	107.6	89.8	83.5	71.8
17	56.5	108.8	61.8	107.6	75.7	80.0	57.6
19	48.0	89.2	60.5	96.7	63.7	62.7	49.9
21	54.4	91.7	49.0	96.1	59.7	70.4	43.7
23	123.8	122.7	52.3	156.8	56.6	65.1	40.6
25	115.0	104.6	44.7	130.4	60.7	78.8	36.2
27	88.7	91.9	41.2	93.1	43.3	65.5	33.8
29	73.6	96.7	41.0	78.3	51.5	72.5	41.0
38	47.8	88.2	30.8	67.7	44.6	82.9	47.8
45	41.2	80.3	40.1	74.5	42.3	60.2	40.1
52	37.2	54.2	27.6	63.5	28.7	39.9	24.4
59	35.7	48.4	33.6	55.6	24.2	41.0	29.4
Average emission	63.1	98.2	59.5	99.0	71.1	77.4	87.6

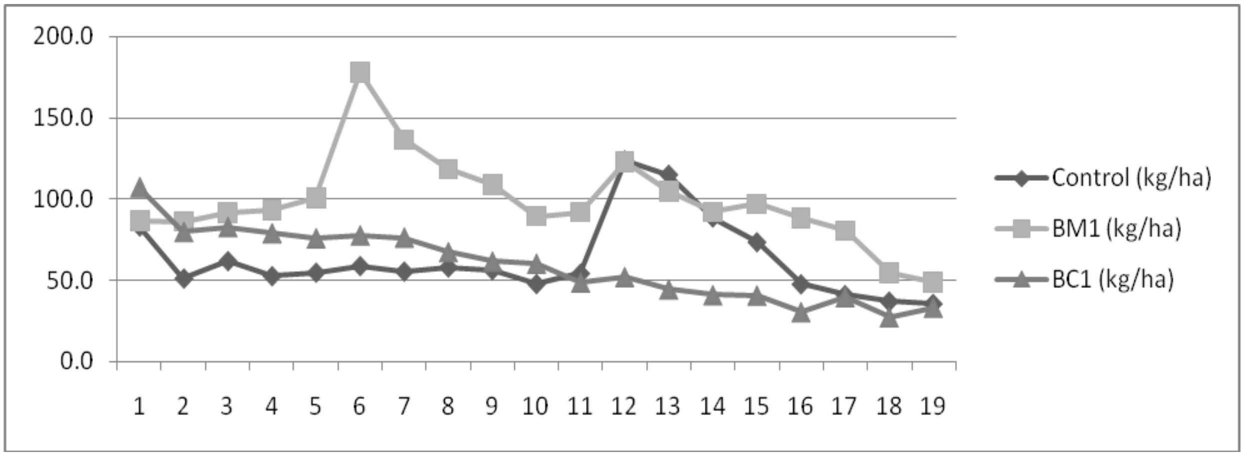

Fig. 3 (a). Emission trends of carbon dioxide from Control, BM-1 and BC-1 soils.

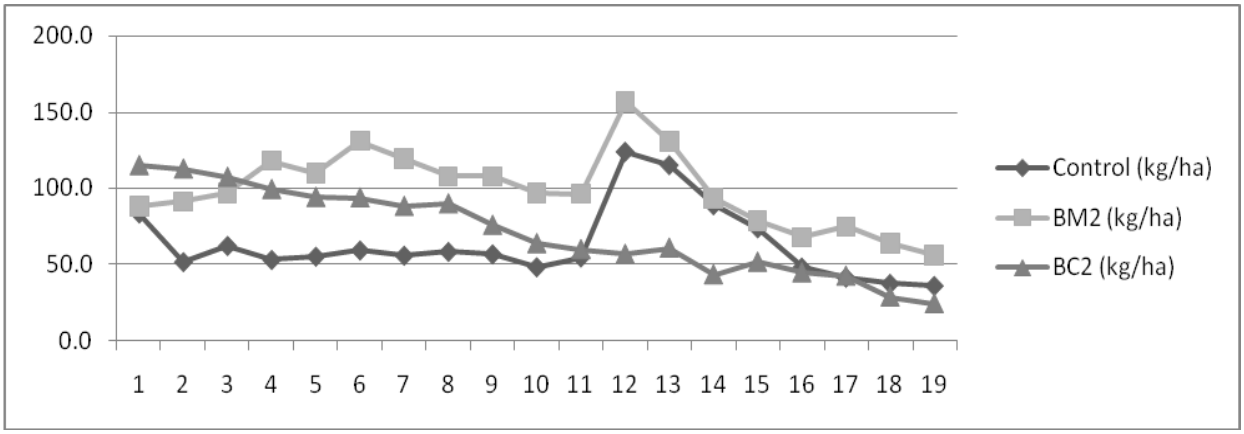

Fig. 3 (b). Emission trends of carbon dioxide from Control, BM-2 and BC-2 soils.

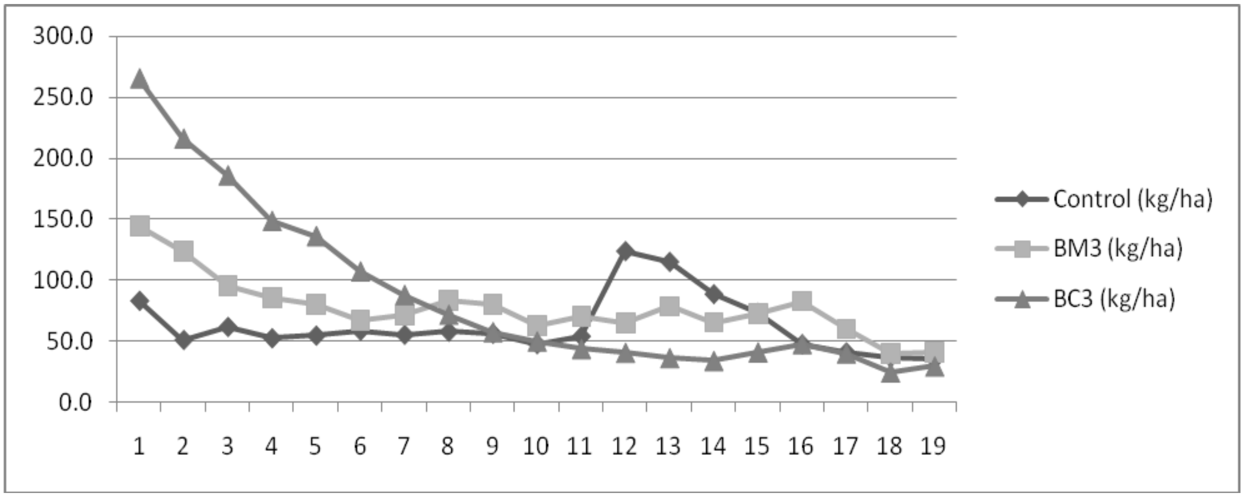

Fig. 3 (c). Emission trends of carbon dioxide from Control, BM-3 and BC-3 soils.

5% level. However, the observations indicated that biochar had a visible positive effect in reducing carbon dioxide emission from soil only after a certain period (16 days after the initiation of the experiment). It concurs with the findings of Yoo and Kang (2012) and Kammann *et al.* (2012) who stated that biochar created at higher pyrolysis temperatures caused a greater reduction in cumulative CO_2 release. Similar findings have also been mentioned by Qayyum *et al.* (2012) who measured cumulative CO_2 released from three soils amended with either nothing, wheat straw (biomass), hydrochar (200°C), low-temperature biochar (sewage sludge pyrolyzed at 400°C), or charcoal (550°C). Cumulative CO_2 released generally followed the order: wheat straw (biomass) > hydrochar > low temperature biochar > charcoal = control. In our experiments, however, few erratic features were observed for carbon dioxide emission from BC-3 soil. In contrast to a high initial emission quantity (265.7kg/ha on day 1), the emission however gradually reduced eventually at the termination of the experiment. The soil incorporated with the corresponding biomass, BM-3, showed a low and steady pace throughout (Table 2 and Fig. 3c). The average emission of carbon dioxide from BC-3 soil and BM-3 soil were 87.6 kg/ha and 77.4 kg/ha, respectively (Table 2). Regardless of the treatments, Control, BM-1 and BM-2 soils showed a similar high emission peak at the fourth week of emission while the soils treated with the corresponding biochars did not show the peak, rather they exhibited a declining trend throughout (Figs. 3 a, b, c).

Impact of Biomass and Biochar on the Evolution of Carbon Monoxide from Soil

Results relating to the evolutions of carbon monoxide (kg/ha) are presented in the table 3 and the pattern of CO evolution is graphically presented in the figures 4 (a, b, c). In contrast to what has been observed for carbon dioxide emission, the soils treated with biochars, regardless of their disparate sources showed no significant effect in reducing carbon monoxide (P= 0.921 on day 30 and P=0.997 on day 60 at 5% level). The quantities emitted and the trend of emission from all the soils showed an anomalous pattern (Table 3 and Figs. 4 a, b and c). It was also observed that the average emission of carbon monoxide was the highest from the soil treated with biochar produced from saw dust (BC-3 soil) (3.64 kg/ha) over the other treatments in a 60 days period whereas the lowest average emission was observed from the control soil (3.54 kg/ha) (Table 3).

Carbon monoxide is apparently produced from the thermal decomposition of humic acids and other organic material (Conrad and Seiler, 1985). It appears that biochar has no significant effects on carbon monoxide emission. This is somewhat unexpected as due to biochar's inherent stability, it is hypothesized that application of biochar to soils results in greater soil carbon sequestration potential than would result from application of biomass of similar carbon content (Kwapinski *et al*., 2010). But as the soil surface is in contact with oxygen in the containers, majority of the carbon monoxide might have oxidized to carbon dioxide.

Impact of Biomass and Biochar on the Evolution of Phosphine from Soil

The effects of biochar and biomass on the evolution of phosphine (g/ha) from soil are presented in the table 4 and the pattern of phosphine evolution is graphically presented in the figures 5 (a, b, c).

Table 3. Quantities of carbon monoxide (kg/ha) emitted from differently treated soils.

Day	Control	BM-1	BC-1	BM-2	BC-2	BM-3	BC-3
3	3.31	3.31	3.28	3.31	3.26	3.31	3.26
5	3.28	3.34	3.46	3.34	3.46	3.43	3.49
7	3.41	3.43	3.47	3.43	3.51	3.47	3.52
9	3.49	3.49	3.49	3.49	3.52	3.48	3.54
11	3.56	3.62	3.54	3.55	3.55	3.54	3.54
13	3.59	3.59	3.65	3.59	3.63	3.61	3.59
15	3.53	3.51	3.58	3.51	3.57	3.54	3.57
17	3.41	3.64	3.69	3.64	3.70	3.69	3.72
19	3.72	3.73	3.73	3.73	3.74	3.72	3.75
21	3.54	3.59	3.67	3.59	3.69	3.64	3.71
23	3.78	3.87	3.92	3.87	3.93	3.92	3.96
25	3.75	3.76	3.79	3.76	3.79	3.79	3.79
29	3.83	3.82	3.77	3.82	3.79	3.77	3.81
38	3.28	3.25	3.32	3.25	3.31	3.27	3.31
45	3.13	3.17	3.30	3.17	3.34	3.27	3.38
52	3.74	3.84	3.96	3.84	3.98	3.95	3.99
59	3.90	3.94	3.94	3.94	3.95	3.92	3.93
Average emission	3.54	3.58	3.62	3.58	3.63	3.61	3.64

Table 4 and figure 5 (a, b and c) show that regardless of various applied treatments, all the soils have followed, though fluctuating, a resembling pattern. A steeper decreasing trend is particular in the biochar treated soils (Figs. 5 a, b and c). Soils treated with biochars exhibited lesser quantities of phosphine emission on an average compared to biomass treated soils as well as to the Control soil (Table 4). The average emission of phosphine from Control soil is the highest and soils receiving biochar treatments emitted the least (Table 4). The average emission from BM-1 soil (0.15gm/ha) is higher compared to BC-1 soil (0.13gm/ha) and this is true for the

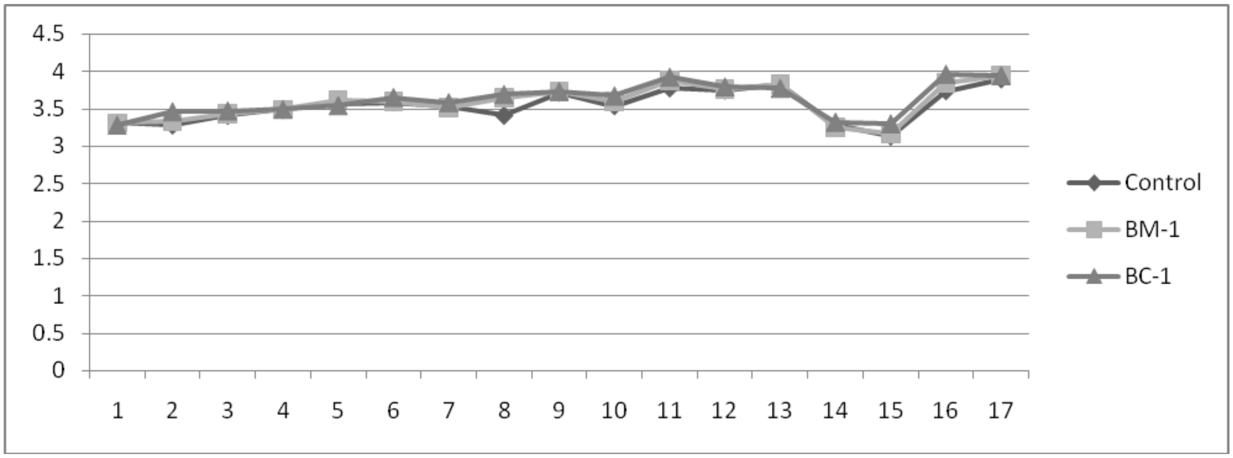

Fig. 4 (a). Emission trends of carbon monoxide from Control, BM-1 and BC-1 soils.

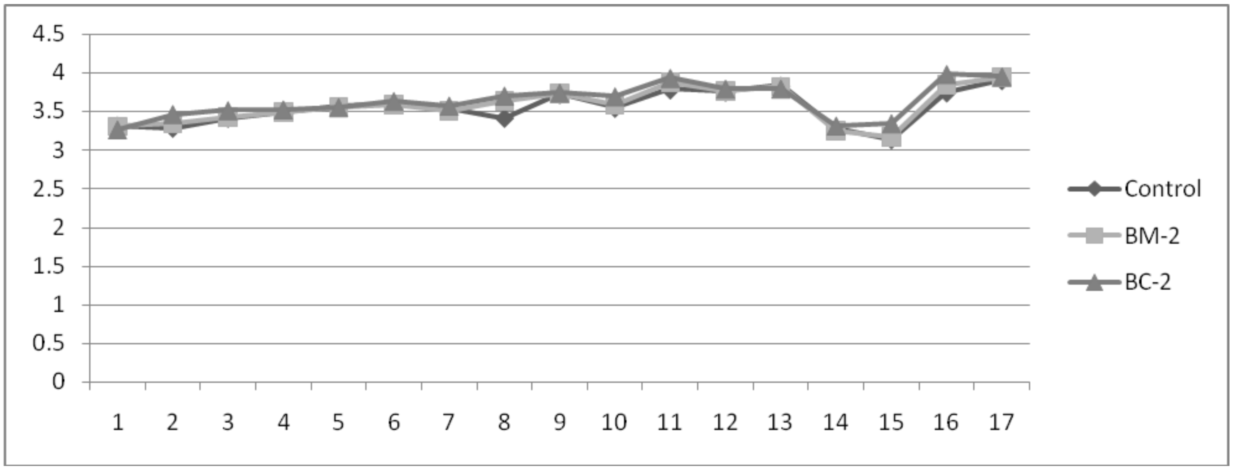

Fig. 4 (b). Emission trends of carbon monoxide from Control, BM-2 and BC-2 soils.

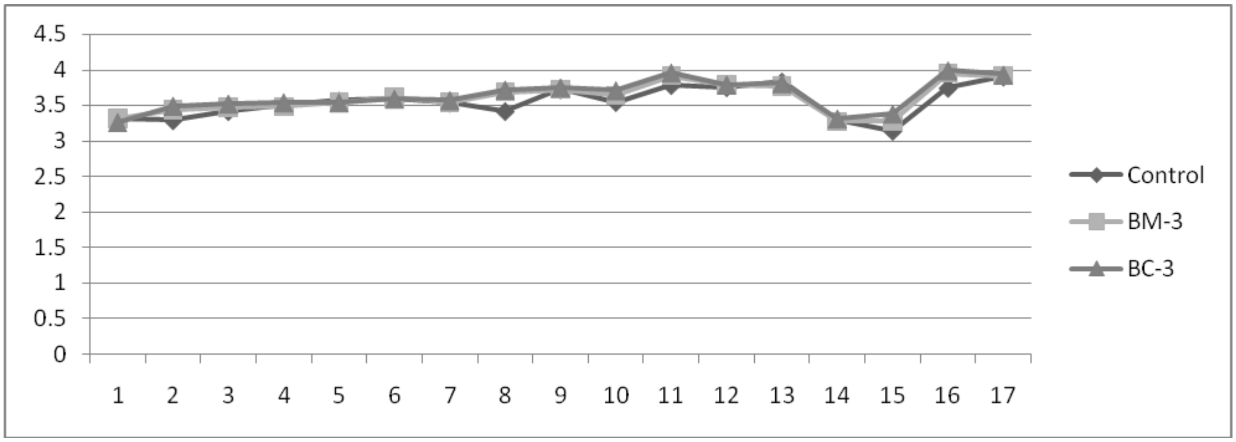

Fig. 4 (c). Emission trends of carbon monoxide from Control, BM-3 and BC-3 soils.

rest of the soils where phosphine emission from biomass (straw and saw dust) treated soils exceeded the average emission quantities compared to their corresponding biochar treatments (0.14 gm/ha from both biomass treated soils and 0.13gm/ha from both biochar treated soils) (Table 4).

Although, emission from saw dust treated soil was fairly high (0.13 gm/ha on day 7) from the inception compared to soil treated with corresponding biochar (0.09 gm/ha on day 7) yet, by the end of the experiment, BC-3 soil yielded far less (0.16 gm/ha on day 59) phosphine compared to BM-3 soil (0.19gm/ha on day 59) (Table 4). The initial emission from BM-1soil (0.13gm/ha on day 5) is lower compared to BC-1 soil (0.16gm/ha on day 5). In the mid-phase of the experiment phosphine emission from BC-1 is lower than the BM-1 soil on several occasions (Table 4) and finally by the terminal period of the experiment BC-1 yielded lower than BM-1 on an average (Table 4).

Gundale and DeLuca (2006) assessed that combustion or charring of organic materials can greatly enhance phosphorus availability from plant tissue by disproportionately volatilizing carbon and by cleaving organic phosphorus bonds, resulting in a residue of soluble phosphorus salts associated with the charred material which in turn will increase the phosphine emission from soil. The available phosphorus content in biochar treated soils have been found to have greatly increased compared to biomass treated soils after 60 days of incubation at field capacity (Personal communication, Khadiza Tahera Khan) and the conducted study complies with this finding as because decreased trends in emission of phosphine from biochar treated soils is observed. Moreover, several bacteria for instance, *Bacillus krulwichiae*, *Bacillus flexus*, *Bacillus sylvestris Aneurinibacillus aneurinilyticus*, *Paenibacillus apiaris*, *Bacillus siralis*, and *Bacillus badius* have been found in the differently treated soils after 30 days (Personal communication, Tazeen Fatima Khan) and perhaps these micro organisms are responsible for reinitiating the emission of phosphine gas after 30 days of incubation. The results are valid on a statistical ground indicating their significance (P value 0.00) at 5% level and indicate that biochar has a positive effect in reducing phosphine production from soil, however, this effect is visible only after a certain period (18 days after the initiation of the experiment)

Impact of Biomass and Biochar on the Evolution of Volatile Organic Compounds from Soil

The effects of biomass and biochar on the retention of volatile organic compounds (g/ha) from soils are presented in the table 5 and the patterns of VOCs are graphically presented in the figures 6 (a, b, c).

Table 5 and the figure 6 (a, b, c) express that regardless of

Table 4. Quantities of phosphine (gm/ha) emitted from differently treated soils.

Day	Control	BM-1	BC-1	BM-2	BC-2	BM-3	BC-3
3	0.12	0.12	0.12	0.12	0.15	0.12	0.12
5	0.16	0.13	0.16	0.13	0.16	0.16	0.13
7	0.13	0.13	0.09	0.09	0.09	0.13	0.09
9	0.13	0.13	0.13	0.16	0.13	0.16	0.13
11	0.16	0.16	0.13	0.16	0.16	0.13	0.16
13	0.16	0.16	0.16	0.13	0.13	0.16	0.13
15	0.13	0.13	0.10	0.13	0.13	0.13	0.13
17	0.19	0.19	0.19	0.19	0.19	0.19	0.19
19	0.19	0.22	0.16	0.19	0.16	0.16	0.16
21	0.16	0.16	0.19	0.19	0.16	0.19	0.16
23	0.22	0.19	0.16	0.19	0.16	0.16	0.16
25	0.19	0.13	0.10	0.13	0.10	0.13	0.10
29	0.09	0.09	0.06	0.13	0.06	0.09	0.06
38	0.10	0.06	0.03	0.03	0.03	0.06	0.03
45	0.10	0.10	0.10	0.10	0.10	0.10	0.10
52	0.22	0.19	0.19	0.19	0.16	0.19	0.16
59	0.19	0.19	0.19	0.19	0.19	0.19	0.16
Average emission	0.15	0.15	0.13	0.14	0.13	0.14	0.13

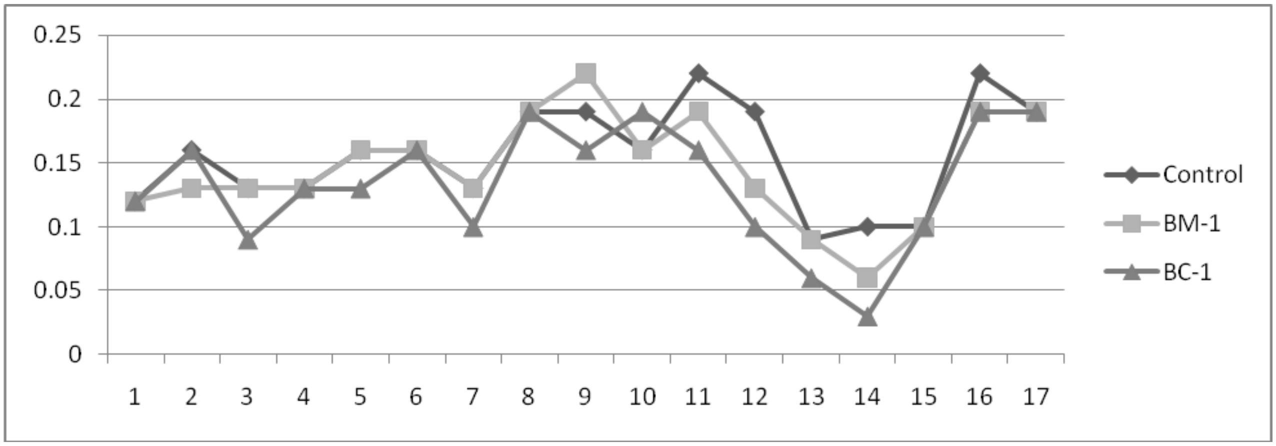

Fig. 5 (a). Emission trends of phosphine from Control, BM-1 and BC-1 soils.

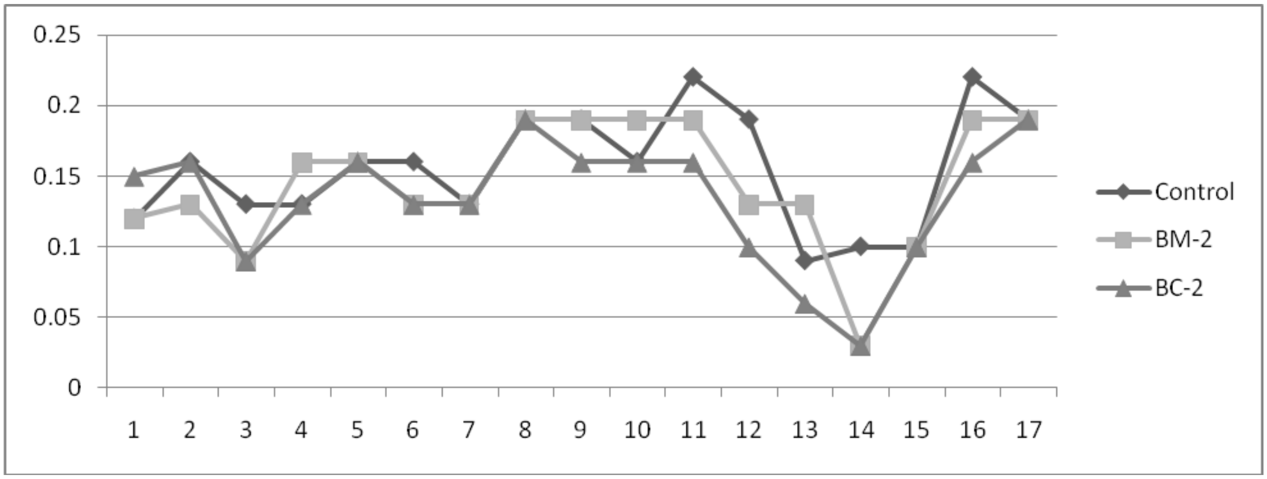

Fig. 5 (b). Emission trends of phosphine from Control, BM-2 and BC-2 soils.

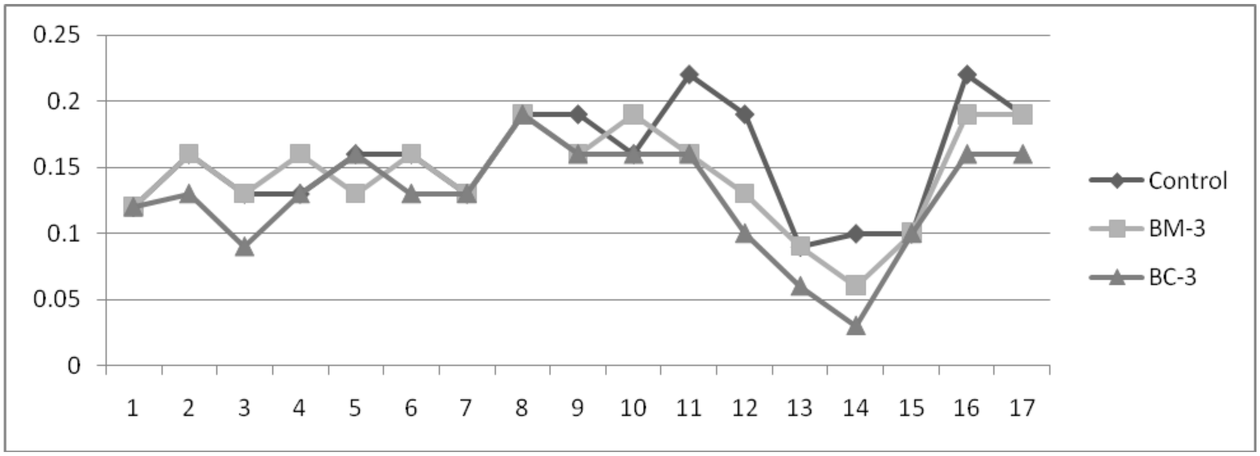

Fig. 5 (c). Emission trends of phosphine from Control, BM-3 and BC-3 soils.

various applied treatments, the production of volatile organic compounds followed a definite pattern in all cases. The Control soil showed the least amount of volatile organic compound production. On an average, emission was the least from the Control soil (9.5gm/ha) whereas soil receiving biochar treatments of saw dust, BC-3 soil, yielded the highest amount (10.4gm/ha) which was almost identical compared to the emission from its corresponding biomass (10.3gm/ha) (Table 5). The average emission from soils treated with biomass rice husk was (10.08gm/ha) higher than their corresponding biochar (9.37gm/ha) treatments, whereas emission from the soils having biomass straw also expelled higher (10.3gm/ha) amount compared to the soil treated with the corresponding biochar (9.6 gm/ha) (Table 5). Among the biochar treated soils, average emission of volatile organic compounds from BC-1 (9.37gm/ha) was the least indicating the fact that rice husk biochar is better in suppressing volatile organic compounds loss (Table 5).

To surmise, except for BC-3 soil, the retention of volatile organic compounds was more prominent in the case of soil treated with biochar produced from rice husk (BC-1 soil) than all the biomass treated soils. Statistical analysis, based on the empirical data, revealed significant results (P value 0.426) at 5% level and this phenomenon was only visible after 5 days of the experiment.

A very interesting feature of volatile organic compounds emanation from soil was observed in the mid- phase of the experiment. During the fourth and fifth week, discharge of VOCs from all the soils, regardless of their applied treatment, reduced down to nearly nil and on day 29, emission from the soils treated with biochars literally seized to exist (0.00gm/ha) (Table 5 and Figs. 6 a, b and c). This might have ensued from the fact that after 30 days, soils were exhausted of carbonaceous compounds; the microbes could not attack biochar and biochar adhered particles due to the recalcitrant factor. After sixth week, emission restarted and gained an increase. This might be due to the microbial metabolism upon the debris (dead cells of microbes) existing within the soil or the activities of some resilient bacteria. Several bacteria for instance, *Bacillus krulwichiae*, *Bacillus siralis*, and *Bacillus badius* have been found in the similarly treated soils after 30 days (Personal communication, Tazeen Fatima Khan) and these might be the reason for the reinitiating of volatile organic compounds emission after 30 days of incubation.

It is well documented that a wide range of highly oxygenated volatile organic compounds (e.g. levoglucosan, hydroxylacetaldehyde, furfurals, methoxyphenols and carboxylic compounds) are retained on the pores of the surface of biochar and some of these compounds have the potentiality to react with nitrous oxide in order to fix it within the soil (Milne *et al.*, 1998) and this is in agreement with the present observations.

CONCLUSION

The Global temperature rise and its consequences have long been debated over the last century. Despite of all the debates, numerous studies explained that the earth is gradually warming up due to the greenhouse effect. New and substantial measures are needed to be employed in order to combat this crisis and mitigating the greenhouse gases should be the focal concern. Along with anthropogenic activities, soil itself emits greenhouse

Table 5. Quantities of volatile organic compounds (gm/ha) emitted from differently treated soils.

Day	Control	BM-1	BC-1	BM-2	BC-2	BM-3	BC-3
3	9.5	10.08	11.26	10.4	12.2	10.7	11.0
5	12.0	11.98	10.09	11.7	12.3	11.4	12.3
7	11.4	11.08	10.77	11.1	10.4	11.4	10.1
9	12.4	12.36	13.31	13.3	13.6	13.3	13.0
11	14.9	15.17	14.85	15.5	14.9	15.8	15.2
13	14.2	14.16	12.59	14.2	12.6	14.5	13.2
15	9.8	10.78	12.04	11.4	12.7	12.0	12.4
17	13.4	14.39	14.71	14.7	16.6	15.0	16.3
19	15.9	16.57	15.61	16.2	14.7	15.6	14.7
21	10.2	10.56	10.56	9.6	9.9	10.6	10.6
23	8.3	12.49	11.85	12.5	11.5	11.8	11.2
25	0.2	0.29	8.31	0.2	10.2	0.2	7.0
29	0.3	2.84	0.0	4.7	0.0	2.2	0.0
38	8.0	7.65	5.74	7.7	4.8	7.7	5.1
45	6.3	6.66	3.80	6.3	3.2	6.7	7.0
52	7.3	7.33	3.50	8.6	2.9	8.3	8.0
59	6.9	6.94	0.32	7.6	1.6	7.6	9.1
Average emission	9.5	10.08	9.37	10.3	9.6	10.3	10.4

gases through natural means as well as through human induced actions like intensive agriculture. There are significant scopes for greenhouse gas mitigation in agriculture, but for the potential to be completely realized numerous barriers need to be overcome. To minimize the emission of these greenhouse gases and some other harmful gases to the environment a relatively new but revised approach is the utilization of biochar. The application of biochar as a significant means of mitigating carbon dioxide, carbon monoxide and other harmful gases

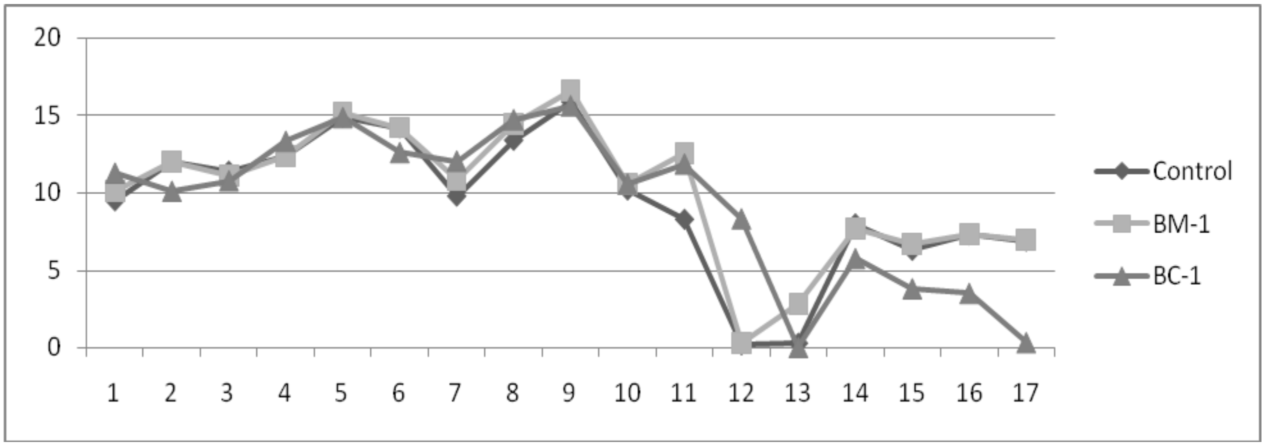

Fig. 6 (a). Emission trends of volatile organic compounds from Control, BM-1 and BC-1 soils.

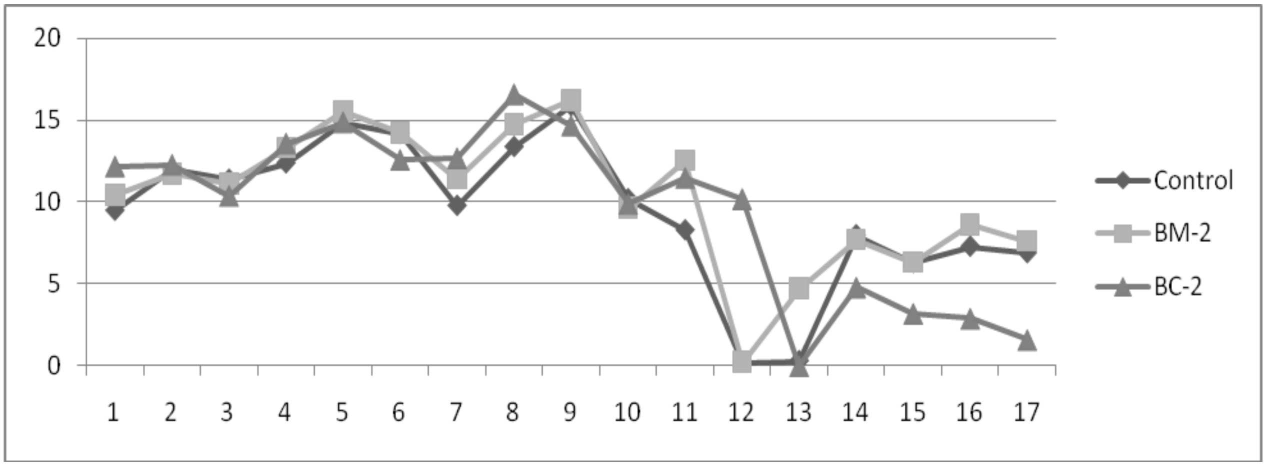

Fig. 6 (b). Emission trends of volatile organic compounds from Control, BM-2 and BC-2 soils.

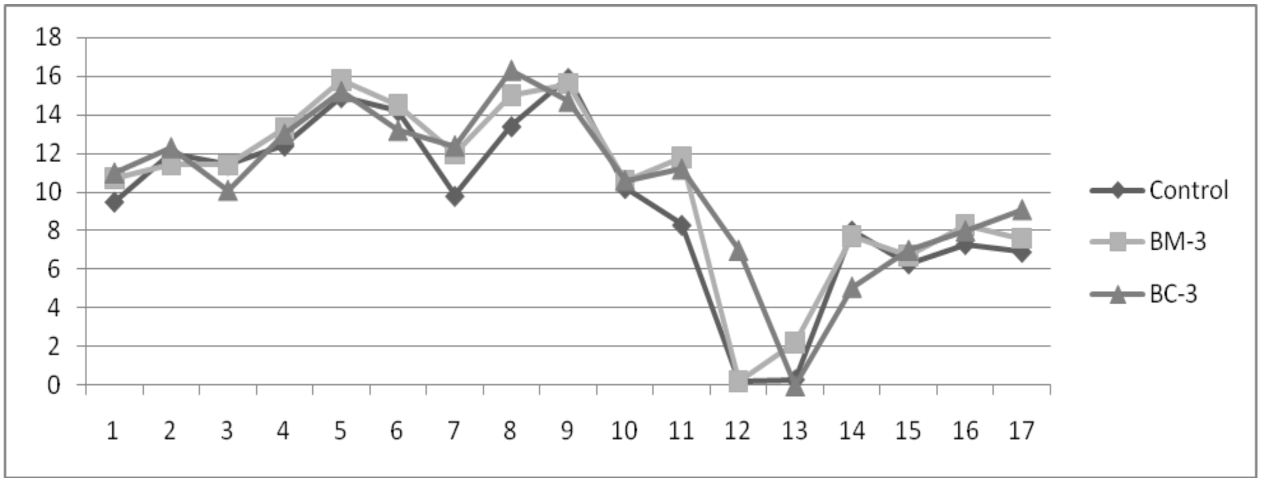

Fig. 6 (c). Emission trends of volatile organic compounds from Control, BM-3 and BC-3 soils.

like phosphine and retaining volatile organics in soil could be highly beneficial to Bangladesh and the rest of the world. This is a simplistic low cost means of adding nutrients to soil and helping agriculture flourish. It can, therefore be useful in the developing countries. With carbon capturing, there is very little impact on people or other organisms and the effects of global warming could be reduced. Environmental protection and human health will be the leading benefactors in large scale biochar production.

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