Redox chemistry and nutrient release from organic amended terrace soil under anaerobic incubation

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Abstract

Aims: To examine the changes in pH and Eh values of terrace soils during anaerobic incubation when amended with different organic materials, and to study N, P and S release from different manure and bio-slurry in terrace soil under anaerobic condition.

Study design: The experiment was carried out following Complete randomized design (CRD) with two replications.

Place and Duration of Study: The soil sample was collected from the surface (0-15 cm) of a selected area of Bhaluka, Mymensingh. Cowdung and Cowdung bioslurry were collected from the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh, in December 2014.

Methodology: The quality and quantity of carbon from different organic sources influence the redox chemistry of soil which in turn affects nutrient availability. The changes in soil pH, Eh and release pattern of N, P, and S from some organic materials in terrace soil under anaerobic incubation were investigated during December 2014 to April 2015. The soil was amended with all the treatments at 2g 100 g-1 (air dry basis) soil and incubated for 14 weeks at 25° C. The N, P and S release were determined by the measurement of NH4-N, phosphate P and SO4-S on destructive sampling at every two weeks.

Results: The pH values increased at initial stage but gradually decreased over time to neutral and the soil became reduced with the advancement of incubation, it varies (1-3 weeks) depending on the quality of organic matter used. The reduction potential showed a significant variation among the treatments. Overall, when the pH values were averaged over the weeks, the highest pH value was measured in PB amended soil followed by poultry manure (PM), cow dung bio-slurry (CDB) and cow dung (CD) amended soils and the lowest was in control. In case of Eh, the most negative (-133.08) Eh value was measured in PM amended soil followed by poultry bio-slurry (PB), CD and CDB amended soils. Control soil had comparatively positive Eh value. At the end of incubation, the highest amount of NH_4-N found in CDB followed by CD, PM, PB and the lowest was in control; the highest amount of phosphate P found in PB followed by PM, control, CDB and CD; the highest amount of SO_4-S found in PB followed by PM, CD, CDB and the lowest was in control.

Conclusion: PB is the best source of organic amendment with respect to release of P and S, whereas CDB showed the best performance in release of N. Nutrient release and availability in reduced environment in terrace soil are a function of soil redox chemistry which is influenced by the quality and quantity of organic matter.

Keywords: Redox potential, Soil, Bio-slurry, Anaerobic incubation, Organic matter.

1. INTRODUCTION

Soil organic matter (SOM) is the very foundation for healthy and productive soils. Understanding the role of organic matter (OM) in maintaining healthy soil is essential for developing ecologically sound agricultural practices. SOM is the organic component of soil, consisting of three primary parts including small (fresh) plant residues and small living soil organisms, decomposing (active) OM, and stable OM (humus). It is essential for maintaining soil health and considered as the life of soil as well as the storehouse of plant nutrients (1). Good soil should have an OM content of at least 2.5% (2).

Maintenance of soil fertility, acidity, and alkalinity is a prerequisite for long term sustainable crop production and it is certain that organic manure (CD, PM, and their slurry) can play a vital role in the sustainability of soil fertility, maintenance of soil pH and crop production. However, the OM content in most of the Bangladesh soils is alarmingly low. So, the maintenance of SOM is a burning issue both for the farmers and agricultural scientists. The application of the bi-product of the recently popularized biogas technology named 'bio-slurry' in soil could be one of the options to maintain soil fertility in Bangladesh. More than 25,000 biogas plants of varying gas-producing capacities (2-6 m^3) are generating more than 200,000 tons of slurry on a dry weight basis (3). Proper application of these huge amounts of bio-slurry to cropland may help to improve SOM status. Incorporation of crop residues increases the supply of carbonaceous materials as an energy source for microorganisms. These lead to a series of biological transformations e.g. mineralization, nitrification, and denitrification. Upon mineralization, crop residue supplies essential plant nutrients (4).

Rice is the main staple food of Bangladesh. Organic amendment in rice fields is hypothesized to change the redox potential and pH of soil depending on the quality of amended OM. Redox potential (Eh) of soil largely influences the production of crops as many of the nutrients turns to its available form under reduced condition. The reduction process leads to oxygen depletion and reduction in soil oxidation Eh followed by a chain of soil chemical changes. The processes that follow include denitrification, reduction of iron, manganese, and sulfate, and changing soil pH and Eh (5). For example, in a typical series of reductions $NO_3^-$is reduced to N_2, Mn^{+4} to Mn^{+2}, Fe^{+3} to Fe^{+2}, $SO_4^-$to H_2S, S^{2+} or HS^- (depending upon pH) and accumulations of acetic and butyric acids that are produced by microbial metabolism (5, 6).

The pH of the soil is the most important soil characteristics for crop production. Various processes such as mineralization, nitrification, denitrification is influenced by the availability of soil microorganism as well as soil pH. Microbial activity in soils that are involved with the mineralization of OM and the release of nutrients is greatly influenced by pH. *Nitrosomonas* and *Nitrobacteria* are responsible for ammonification from the decomposition of OM and the oxidation of Ammonia to Nitrite which are greatly influenced by pH. Nitrification being greatly reduced at pH values less than 6 and greater than 8. The reduction potential (redox potential, E_h) is intrinsic parameters of food products that can influence the growth, survival, and metabolism of microorganisms.

In Bangladesh, soil fertility is decreasing day by day which is mainly because the lower amount of nutrient supply during crop production, increasing acidity, decreasing alkalinity, and minimum use of organic manure. Nevertheless, a significant portion of the CD is used for fuel purposes. Under the situation, the production of bio-slurry from cattle or poultry manure deserves due attention. Furthermore, the fertilizer value of CD or poultry manure is slightly increased after gas production. Poultry litter bio-slurry is especially suitable for acid soil as it has a strong liming effect, thus reduces acidity as well as various toxicity. Bio-slurry contains available nutrients, increase soil physical properties, and inhibit weed seed germination and pest attack. So the application of bio-slurry will supply the nutrients in addition to improving the physical, chemical, and biological properties of soil towards improving and conserving soil fertility. Under such situations, to sustain crop productivity and to increase soil fertility, there is no alternative but to add organic fertilizer in the soils. Bio-slurry could be one of the best organic fertilizers to rejuvenate soils since it is a rich source of both plant nutrients and OM. In view of the above-stated facts, the present research was undertaken in achieving the following objectives: i) to examine the changes in pH and Eh values of terrace soils during anaerobic incubation when amended with different organic materials, ii) to study N, P and S release from different manure and bio-slurry in terrace soil under anaerobic condition.

2. MATERIAL AND METHODS

2.1 Collection and preparation of soil sample

The soil sample was collected from the surface (0-15 cm) of a selected area of Bhaluka, Mymensingh in December 2014. The land was fallow during the collection of soil samples. The collected soils were air-dried for several days, ground, plant residues, and other extraneous materials were removed and were sieved through a 10-mesh sieve and mixed thoroughly. This whole process was done several times until an adequate amount of soil was prepared for the experiment. A significant amount of sieved soil was kept in a polyethylene bag for chemical analysis. The morphological, physical, and chemical properties of the initial soil have been presented in Table 2.

2.2 Collection and preparation of organic materials

Various organic materials namely poultry manure (PM), poultry bio-slurry (PB), CD, and CDB were collected from different locations of Mymensingh presented in Table 1. PM and PB were collected from Krishibid Farm Limited, Bhaluka, Mymensingh. CD and CDB were collected from the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh. The manure was air-dried for several days under shaded condition, ground and mixed thoroughly and other extraneous materials were removed. The processed manure was used for the incubation experiment.

Table 1: Chemical compositions of poultry manure, poultry bio-slurry, CD and CDB

Organic amendments	Organic C (%)	Total N (%)	Total P (%)	Total S (%)	C:N	C:P	C:S
Poultry Manure (PM)	35.12	2.52	0.24	0.50	13.94	146.33	70.24
Poultry Bio-slurry (PB)	16.33	1.4	0.24	0.62	11.66	68.04	26.34
Cowdung (CD)	29.63	1.09	0.32	0.24	27.18	92.59	123.45
Cowdung Bio-slurry (CB)	10.12	1.4	0.18	0.14	7.22	56.22	72.29

Source: Rashid (2013)

2.3 Treatment and experimental design

The experiment comprised of five treatments including control. The treatments were as followed: To = No organic matter (control), T_1=Poultry manure, T2= Poultry bio-slurry, T_3= CD, T4 =CD bio-slurry. All the amendments were applied @ 2g/100 g soil. The experiment was carried out following Complete randomized design (CRD) with two replications. The locations of the plastic glasses receiving different treatments were exchanged among the treatments throughout the incubation period at a one-month interval for homogenization.

2.4 Incubation experiment

Incubation studies were conducted under controlled conditions on disturbed soil samples for a period of 14 weeks at 25°C temperature. Plastic glass having an inner diameter of 5.5 cm and a height of 15cm were used as incubation containers. 100 g soil was weighed in each glass and animal residues were added to the soil at the rate of 2g/100g (oven-dry basis) soil. The bulk density of the soil in the glass was adjusted to the field density by compacting the soil to1.2Mg $m^{-3.}$ Soils were oversaturated with a standing water level of 2cm for assessment of anaerobic mineralization. In total, 14 (2 replicates x 7 dates) glasses were filled for each treatment. Every two weeks, soil samples were collected destructively by removing the soil from one plastic glass per replicate.

2.5 pH and Eh value

pH and Eh data were collected from the plastic glasses using pH meter (Samsion TM^+, HACH, USA) and Eh meter (Samsion TM^+, HACH, USA) respectively putting them in the plastic glass. Data on pH and Eh values has been collected every day from 29.12.2014 to 13.01.2015. After that, the data has been collected 2 days' interval from 15.01.2015-22.01.2015 and 1-week interval from 29.01.2015-05.04.2015.

2.6 $NH4^+$-N measurement

NH_4^+-N was extracted from the incubated soils with 0.05M $CaCl_2$ (1:5 soil weight (g): extracting volume (ml) solution. Every two weeks, soils were sampled destructively by removing the soil from one plastic glass for each treatment. In each sampling, the soil of each glass was pasted prior to extraction, and 10g pasted soil was taken in a conical flask and extracted each time with 50ml $CaCl_2$. The conical flasks were shaken for 30 minutes on a shaker. The supernatants were filtered through normal filter paper, fitted in a vacuum holder. Gravimetric soil moisture content was determined for every plastic glass by oven drying a 30 g soil sample at 105°C.

The NH_4^+-N in the incubated soil was measured colorimetrically by the indophenol blue method (Kemper, 1974) as adapted by (7). Briefly, 1 ml of the $CaCl_2$ extract was taken in a 25 ml volumetric flask. Then, 1 ml EDTA was added to the samples and mixed followed by standing for 1 minute. Later on, 2ml of phenol nitropruside reagent was added to the flask, followed by 4ml of the buffered hypochlorite reagent and immediately diluted the flask to 25 ml with NH_4^+ free water and mixed well. The flasks were placed in a water bath maintaining 40°C and allowed to remain 30 minutes for homogenous color development. The flasks were removed from the bath and cooled to room temperature and determined the absorbance of the colored complex with a spectrophotometer (Spectronic GENESYS 5 UV-Vis Spectrophotometer, USA) at a wavelength of 636nm against a reagent blank solution. A series of the standard solution was prepared containing 0, 0.08, 0.16, 0.24, 0.32, 0.40, and 0.48 ppm NH_4^+ solution and prepared a standard curve for determining the NH_4^+-N concentration of the sample.

Table 2. Morphological, physical, chemical and mineralogical characteristics of Noadda soil of Bhaluka and Mymensingh

Morphological		Physical		Chemical		Mineralogical	
AEZ	Madhupur tract	Sand (%)	10.0	pH_{KCl}	3.7	Mica (%)	39
Soil Tract	Madhupur tract	Silt (%)	46.0	Organic carbon (%)	0.92	Smectite (%)	0
Soil series	Noadda series	Clay (%)	44.0	Organic matter (%)	1.59	Vermiculite (%)	4
Soil Type	UlticUstocrepts	Textural class	Silty clay	Total N (g/kg)	1.0	Chlorite (%)	13
Topography	High land			NH_4-N(mg/kg soil)	3.35	Kaolinite (%)	16*
Drainage	Moderate			NO_3-N (mg/kg soil)	6.0	Vermiculite-chlorite interstratified (%)	0
Cropping Pattern	Fallow-Fallow-Rice			Available P (mg/ kg soil)	33.9	Mica-chlorite interstratified (%)	0
				Available S (mg/kg soil)	12.9	Guartz (%)	19
						Goethite (%)	0
						Lepidocrocite (%)	1
						Feldspar (%)	9

(Source: Kader *et. al.,* 2015)*Also contain interstratified Kt-St

2.7 Phosphorus measurement

Phosphate P mineralization was measured under controlled anaerobic conditions for 14 weeks on disturbed soil samples. Every two weeks, soils were sampled destructively by removing the soil from a plastic glass per replicate. Mineralizable phosphate P was extracted from soil by shaking with 0.5M $NaHCO_3$ solution at pH 8.5 following the method of (8). The soils were pasted prior to extraction and 10 g pasted soil was taken in a conical flask and 1 g carbon black was added, then extracted each time with 100ml 0.5M $NaHCO_3$ solution. The conical flasks were shaken in the dark for 30 minutes on a shaker. The supernatants were filtered through Whatman (42) filter paper, fitted in a vacuum holder. Gravimetric soil moisture content was determined for every tube by oven drying a 30 g soil sample at 105°C.

The phosphorus content in the sample was measured by the Olsen method. Ammonium molybdate solution was made using potassium antimony tertarate, conc. H_2SO_4 and ascorbic acid. 5 ml of this solution was added to 5 ml of the $NaHCO_3$ extracted volume was made up to 50 ml. Then P content in the water sample was determined by spectrophotometer at 890 nm wavelength.

2.8 Sulphur measurement

Sulphur mineralization was also measured under the controlled anaerobic condition for 14 weeks on disturbed soil samples likewise N and P. The soil was mixed thoroughly and 10g pasted soil was taken in a conical flask and extracted each time with ml $CaCl_2$ (0.15%) for S measurement described by Williams and Steinbergs (9). The conical flasks were shaken in the dark for 30 minutes on a shaker. The supernatants were filtered through normal filter paper, fitted in a vacuum holder. Gravimetric soil moisture content was determined for every tube by oven drying a 30 g soil sample at 105°C. The sulphur content in the $CaCl_2$extractswas determined turbidimetrically and the turbid was measured by spectrophotometer at 420 nm wave length.

2.9 Data analysis

The pH value, Eh value, ammonification, P mineralization, and rates were estimated by fitting a zero-order kinetic model: $N(t) = N_0 + kt$

where t is the time (in week), $N(t)$ is the amount of NH_4-N, Phosphate-P at time t, N_0 is the initial amount of NH_4-N, Phosphate-P (mg P kg^{-1}), and K is the mineralization rate (mg kg^{-1} $week^{-1}$).

The data were statistically analyzed by one-way ANOVA (analysis of variance) with the help of SPSS (Statistical package for social science) to see whether the influence of different treatments on these parameters was significant or not. The means of different treatments were compared by Duncan's New Multiple Range Test (10) to test the significance of variation between the treatment means. All other analysis was carried out by MS EXCEL 2000 (version 7.0).

3. RESULTS

3.1 pH value in amended soils

The terrace soil amended with different OM treatments (PM, PB, CD, CDB) along with a control. The pH values of the soil as influenced by different organic amendments were presented in Figure 1. The pH values significantly differed among the treatments throughout the incubation period. Although the pH value differed throughout the incubation period but gradually become a turn to neutral in the advancement of incubation. The pH value was increased in the day due to the addition of water in the soil on 12 January 2015, 27 February 2015, and 15 March 2015. The pH value of PB amended soil was significantly higher compared to other treatments in the first week but become neutral at the last of the incubation period. However, the pH values of poultry manure amended soil shows the highest value (7.88) on 30 December 2014, and CD amended soil shows the lowest value (6.12) on 01 January 2015. The pH value of PB amended treatment was found the highest among the treatments most of the weeks during the whole course of incubation (Figure 1).

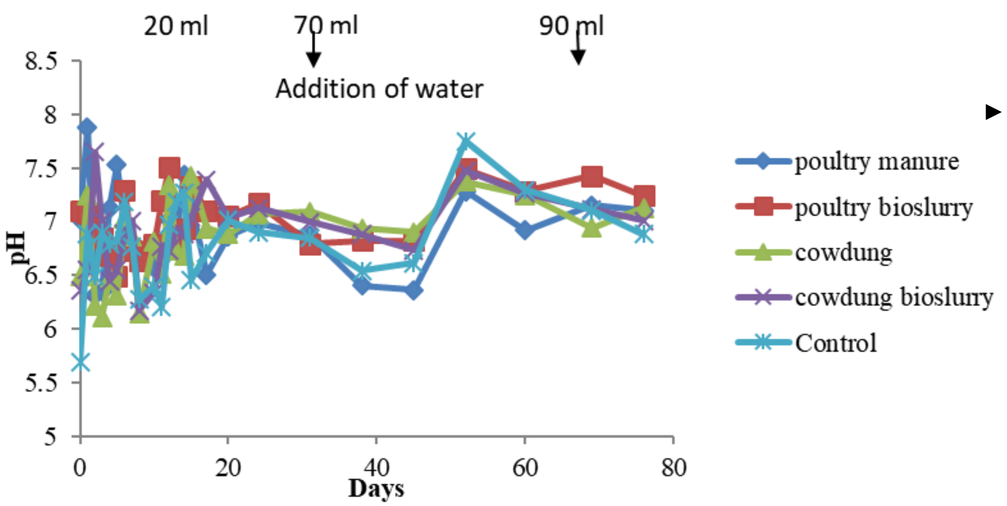

Fig. 1: pH values in terrace soil as influenced by different organic materials during 14 weeks of incubation

However, when the pH values were averaged over the weeks, the highest pH value was measured in PB amended soil followed by PM, CDB and CD amended soils and the lowest was in control (Figure 2).

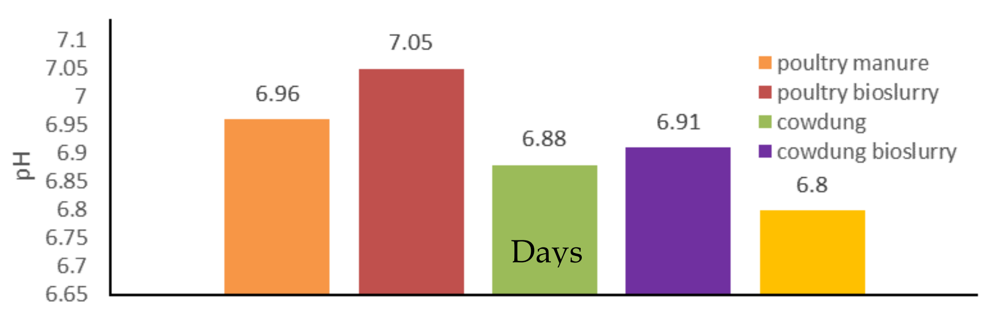

Fig. 2: Average pH values in terrace soil as influenced by different organic materials during 14 weeks of incubation

3.2 Eh value in amended soils

The weekly Eh values of terrace soil as influenced by different organic amendments were presented in Figure 3. Organic amended soils were more reduced then the control soil throughout the incubation period. The Eh values significantly differed among the treatments throughout the incubation period. Soils become reduced within seven days of incubation if amended with PM and PB. However, CD and CDB takes around 20 days to reduce the soil. If soil is not amended with any organic amendment, then the control soil takes nearly three weeks to be reduced. However, among the organic amendment, PM and PB kept the terrace soil more reduced compared to CD and CDB. The Eh values were drastically increased in last week due to low water.

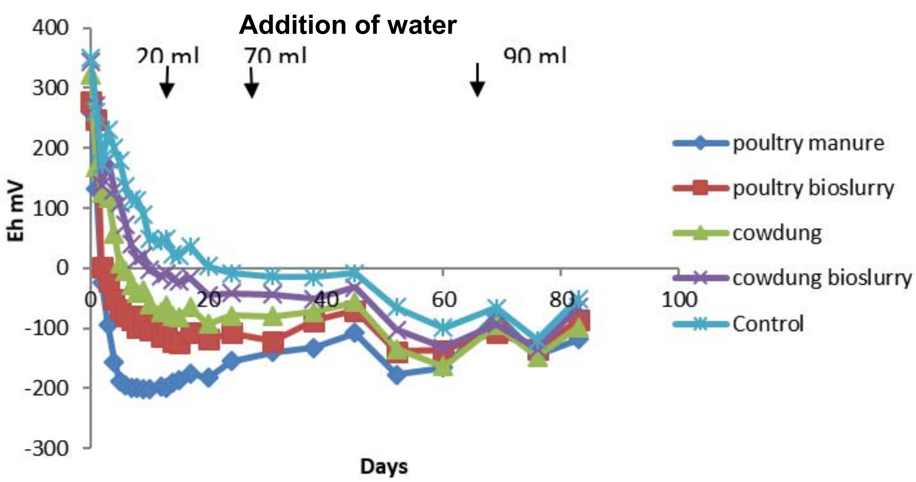

Fig. 3: Eh values in terrace soil as influenced by different organic materials during 14 weeks of incubation

However, when the Eh values were averaged over the weeks, the most negative Eh value was measured in poultry manure amended soil followed by PB, CD, and CDB amended soils. Control soil gave comparatively positive Eh value (Figure 4).

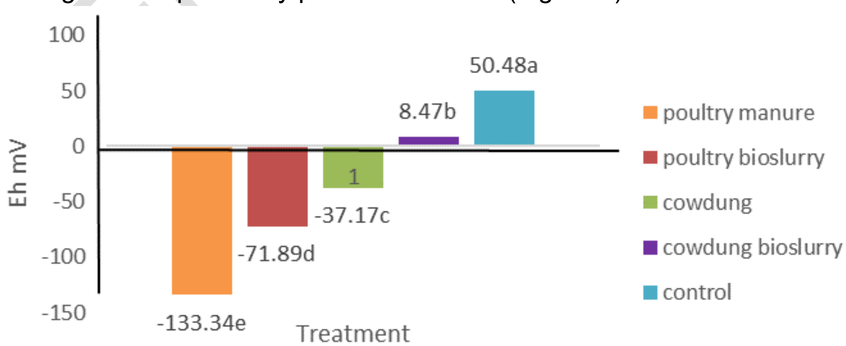

Fig. 4: Average Eh values in terrace soil as influenced by different organic materials during 14 weeks of incubation

3.3 NH_4-N release pattern from amended soils

The soil amendment with manures enhanced NH_4–N content in soils certainly due to additional mineralization of added OM. Figure 4 showed the trend of evolution of NH_4–N in different treatments over time. The evolution of NH_4-N was substantially different during 14 weeks of incubation in all treatments including the control soil. The release of NH_4-N was the highest at the 8th week in CDB amended soil (3.36 mg NH_4-N kg^{-1} soil) and the lowest at 8th week in control soil (0.09 mg NH_4-N kg^{1}soil). The second highest release of NH_4-N was observed at 8th week in CD amended soil (1.94 mg NH4-N kg^{-1} soil) and the second-lowest at 4th week in PB amended soil (0.12 mg NH4-N kg^{-1}soil).

The release of NH_4-N was the highest at the 8th week for CD and CDB amended soils while NH_4-N was the highest at the 6th week for PM and 12th PB amended soils. Between the CD and CDB, NH_4-N mineralization was found comparatively better in CDB amended soil. The highest NH_4-N mineralization of 3.36 mg NH_4-N kg^{-1} soil was found in CD amended soil at 8th week while that was 1.94 NH_4-N mg kg^{-1} soils at 8th week for CDB.

Between the PM and PB, NH_4-N mineralization was found comparatively better in PM amended soil. The highest NH_4-N mineralization of 1.60 mg NH_4-N kg^{-1} soil was found in PM amended soil at 6th week while that was 0.92mg NH_4-N kg^{-1}soil at 14th week for PB (Figure 5). In all the sampling campaigns CDB had higher NH_4^+-N concentration.

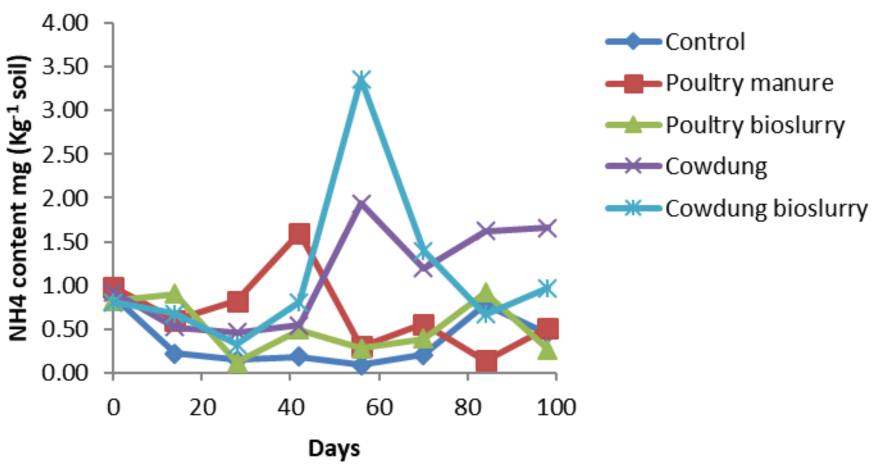

Fig. 5. NH_4-N release in terrace soil as influenced by different organic materials during 14 weeks of incubation

3.4 Available Phosphate P release pattern from amended soils

The soil amendment with manures enhanced Phosphate P content in soils certainly due to additional mineralization of added OM. Figure 6 shows the evolution of Phosphate P in different treatments over time. In general, the evolution of Phosphate P differed with the advancement of incubation period in all amended treatments including the control soil.

In all treatments, the total release of Phosphate P was the highest 8th at a week in PB amended soil (0.69 mg P kg^{-1} soil). The evolution of mineral P was remarkably higher in PM and PB amended soil compared to the CD and CDB amended soil. Between the PM and PB, Phosphate P mineralization was found comparatively better in PB amended soil. The highest P mineralization of 0.69 mg P kg^{-1} soil was found in PM amended soil at 8th week while that was 0.43 mg P kg^{-1} soil at 14th weeks in poultry amended soil. Phosphate P mineralization was found similar in CD and CDB amended soil. The highest Phosphate P mineralization of 0.23 mg P kg^{-1} soil was found in CDB amended soil at 2nd week (Figure 6).

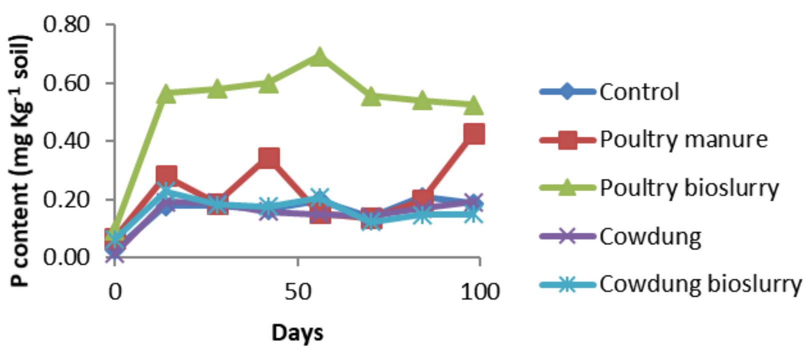

Fig. 6. P release in terrace soil as influenced by different organic materials during 14 weeks of incubation

3.5 Available SO_4-S release pattern from amended soils

The amendment soil with different manures resulted in an increase in SO_4-S content in soils certainly due to mineralization of those OMs. Figure 7 stated the trend of evolution of SO_4-S in soils against different treatments over time. In most of the treatments, the evolution of SO_4-S was substantially higher in all the samples than control soil. The release or accumulation of SO_4-S was highest in 14th week in PB amended soil (67.5 mg SO_4-S kg^{-1} soil) and the lowest at 10 weeks in control soil (14.8 mg SO_4-S kg^{-1}soil).

Between the PM and PB, SO_4-S release was found comparatively better in PB. The highest SO_4-S release of 54.4 mg SO_4-S kg^{-1} soil was found in PM amended soil at 8th week while that was 67.5 mg SO_4-S kg^{-1} soil at 14th week in PB amended soil. Between the CD and CDB, SO_4-S release was found comparatively better in CD amended soil. The highest SO_4-S release of 49.1 mg SO_4-S kg^{-1} soil was found in CD amended soil at 14th week while that was 48.3 mg SO_4-S kg^{-1} soil at 6th weeks in CDB amended soil (Figure 7). In general, the evolution of SO_4-S increased with the advancement of incubation period in all amended treatments indicating the continuity of the mineralization of applied and inherent OM in soils.

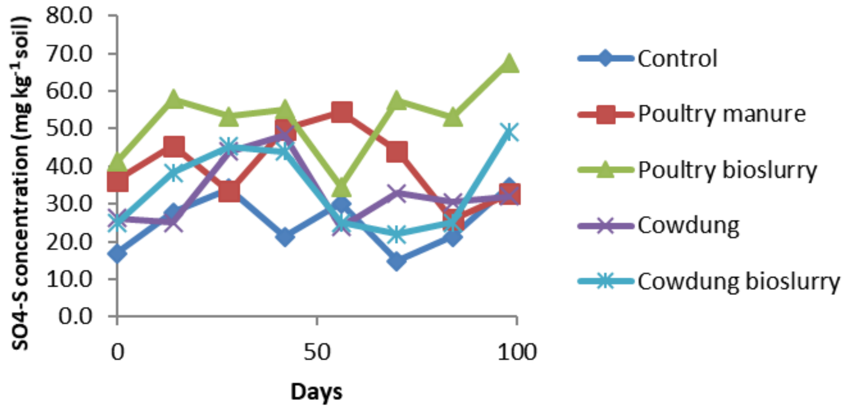

Fig. 7. SO_4^-S release in terrace soil as influenced by different organic materials during 14 weeks of incubation

4. DISCUSSION

The major part of Bangladesh is on the delta formed by the alluvial and marine deposition of sediment. Marine deposited sediments are much older and formed highly weathered terrace soil occupying 8% of the country's total land area. Therefore, terrace soil is less fertile, however, this soil is important for upland cultivation as it is situated 30m above the mean sea level. Thus, Noadda soil was selected as a representative soil of terrace soil. The major two sources of manure used in Bangladesh for long e.g. PM and CD. However, very recently biogas technology is getting popular particularly in rural areas where most of our agricultural lands are situated. More than 25,000 biogas plants already established in the country and generating more than 200,000 tons of slurry on a dry weight basis as a bi-product of biogas. Therefore, poultry and CDB was included in addition to PM and CD and were incubated under the anaerobic condition as the major crop of the country rice is cultivated under wetland condition. Bio-slurry could be one of the best organic fertilizers to rejuvenate soils since it is a rich source of both plant nutrients and OM. Bio-slurry is normally rich in macro and micro nutrients (11). The N, P, and S the three macro nutrients released from manure (PM, PB, CD, and CDB) and the evolution of redoximorphic properties (pH and the Eh) during anaerobic incubation was studied through an incubation experiment at 25^{0}C, the average temperature of Bangladesh.

The pH value differed throughout the incubation period but gradually become turns to neutral in the advancement of incubation. The result showed that in anaerobic condition an increase in pH occurs and then decrease over time. Sahrawat (12) mentioned that the carbon dioxide produced is retained in the flooded soil due to restricted diffusion through standing water layer on the soil surface and this allows large quantities of carbon dioxide to accumulate and form mild acid, which helps in neutralizing alkalinity in the soil. The pH of our study remained mostly closer to neutral ranging from 6.8 to 7.1. The pH value was increased in some of the days due to the addition of distilled water in the soil. When the pH values were averaged over the weeks, the highest pH value was measured in PB (7.01) amended soil followed by PM (7.0), CD (6.9), and CDB (6.9) amended soils and the lowest was in control (6.8). The higher pH value of PB and PM amended treatments might be due to the fact that poultry feeds are very Ca and lime-rich thereby posing higher pH.

The Eh values significantly differed among the treatments throughout the incubation period. The Eh value was gradually decreased with the advancement of incubation. The result showed that the Eh value decreased over time. The results are in agreement with the findings of Sahrawat (12). On an overall, when the Eh values were averaged over the weeks, the most negative Eh value was measured in PM (-135.08) amended soil followed by PB (-74.8, CD (-40.73) and CD (3.9) bio-slurry amended soils. Control (44.55) soil gave comparatively positive Eh value. However, among the organic amendment, PM and PB showed the most negative Eh value compared to CD and CDB. This might be due to the quality of amended organic manure. Organic manure rich in particulate OM is decomposed very quickly hence reduced the environment. Here studied PM was fresh and composed of very labile OM and the CD and CDB were comparatively decomposed that less reduced the soil environment during incubation.

The amounts of NH_4-N release increased with the advancement of the incubation period and reached its peak within 8 to 10 weeks in all the treatments. In most of the treatment, NH_4-N evolution decreased in 4^{th}week. The results showed that the ammonification rate was smaller in bio-slurry amended soil compared to manure amended one. This is particularly true for PM and PB treatments. This might be due to the higher pH of PB that enhanced volatilization losses of evolved NH_4-N. Bitzer and Sims (13) reported that 69 percent of organic N in poultry litter mineralized in 140 days in sandy soil but volatilization takes place instantly on incorporation. Wolf (14) found that 37 % of the total - N in surface-applied PM was volatilized in 11 days.

The release of P increased with the advancement of incubation period in all amended treatments including control soil. The release of mineral P was remarkably higher in PM and PB amended soil compared to the CD and CDB amended soil. PB is very famous as a P source due to its much higher P content. Phosphorus availability from all animal production sources of manure is high (>70%), as most of the manure P is inorganic and becomes plant available after application (15). Poultry diets are made up primarily of plant seeds (usually corn and soybeans). Corn and soybean meals comprise as much as 80 percent of poultry diets. However, much of the P is bound in the phytate phosphorus form and unavailable to the poultry. Phytate-phosphorus within a given feedstuff is variable but typically averages 72% of the total seed P in corn and 60% in soybean meal (16). Because poultry digestive systems lack the phytase enzyme that breaks down and release P, only 10–30 percent of the P in corn and soybean meal is available to poultry (17). Therefore, forms of inorganic P, such as defluorinated phosphate, monocalcium phosphate, and di-calcium phosphate, are often added to the feed to meet dietary requirements. The combination of unavailable P from grain sources and added inorganic P means that much of the total P passes through the birds and ends up in the litter, increasing litter P concentrations (18). Thus, phosphorus occurs in PB and PM in a combination of inorganic and organic forms. In general, 45 to 70 percent of manure P is inorganic. Organic P constitutes the rest of the total P. Therefore, the release of mineral P was much faster in PB and PM amended soil during the incubation period than CD and CDB.

The release of SO_4-S increased with the advancement of incubation period in all amended treatments including control soil. The higher amount of SO_4-S was evolved from PM and PB amended soils over CD, CDB, and control soils throughout the incubation period. Much higher total S content for PM and PB as well as narrower C:S ratio of PM and PB might be the reason for this higher rate of S release compared to the CD and CDB. This is very similar to Sammi Reddy, Singh (19) who reported that the amount of S mineralized in manure amended soils was highest.

5. CONCLUSION

The present study may lead to concluding that the quality of organic materials, as well as soil itself, has a large influence on the changes of pH, Eh, and nutrient releases during anaerobic incubation. The Eh of the studied soil showed a significant variation among the treatments depending on the chemical composition and quality of OM used for soil amendments and the pH was found increased at initial but gradually turns to neutral. pH largely influenced by the lime content of the applied organic materials while the Eh was influenced by the liability of applied organic materials. So, it may be concluded that the application of bio-slurry in the soil had better performance on the release of N, P, S, and the use of manure in soil not only accelerated the release of nutrients but may also maintain soil pH and soil Eh.

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