STUDIES ON THE MINERALIZATION OF P AND S IN CONCENTRATED ORGANIC FERTILIZER IN ANAEROBIC CONDITION UNDER LABORATORY INCUBATION

A THESIS

BY

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Student No. 1701197

Session: January-June, 2023

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IN

SOIL SCIENCE

DEPARTMENT OF SOIL SCIENCE

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY

DINAJPUR-5200

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JUNE, 2024

DEDICATED

TO MY

BELOVED MOTHER

AND

HONORABLE TEACHERS

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June, 2024 *The Author*

ABSTRACT

Having a comprehensive comprehension of the process by which nutrients are released from manure or compost after being applied through mineralization is crucial in order to ensure that the nutritional requirements of crops are fulfilled, to ensure the timely application of fertilizers, and to improve the efficiency of nutrient utilization. The current study was done at the laboratory of the Department of Soil Science of Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, Bangladesh to study the mineralization of N and S in concentrated organic manures in anaerobic condition under laboratory incubation. In this experiment, T_1= Mustard oil Cake, T_2= Fish meal, T_3= Bone meal, T_4= Biochar enriches organic fertilizer, T_5= Vermicompost and T_6= control was used as treatments. The physicochemical properties of the available P and available S, pH and EC was assessed by standard protocol. The mineralization study was performed under anaerobic conditions for 180 days at 25 ^{0}C in the laboratory. The release of P, S, pH and EC showed significant variation in anaerobic conditions. The mustard Oil cake exerted the highest S, P, pH and EC release under anaerobic conditions. pH release vary among the treatments over the study periods. Fish meal gave the second highest result in most of the cases. However, appropriate organic manures should be chosen and applied in the proper quantity to provide exact amounts of essential nutrients, to increase crops nutrient use efficiency and to formulate correct fertilizer recommendations for getting maximum use of different organic manures.

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CHAPTER I

INTRODUCTION

Agriculture plays a crucial role in driving the economy of Bangladesh, contributing 15.0% to the country's gross domestic product (GDP) according to the Bangladesh Economic Review of 2023. Additionally, it employs 43% of the country's workforce as stated in the Statistical Yearbook Bangladesh of 2023. Agriculture in this country has undergone significant changes over time, leading to a dramatic increase in crop production. This can be attributed to the introduction of new technology, mechanisation, greater use of chemicals, increased cropping intensity, the adoption of high-yielding and hybrid varieties, and the cultivation of crops with high biomass potential, among other factors. While the aforementioned changes have yielded numerous favourable outcomes, they have also resulted in several adverse consequences. These include the depletion of topsoil, the extraction of nutrients from the soil, contamination of both ground and surface water, ongoing disregard for the living and working conditions of agricultural labourers, rising production expenses, and the deterioration of economic and social circumstances in rural communities (Agriculture Sector Review, 2023). In order to address the needs of a continuously growing population and ensure food security, it is imperative for our farmers to use inventive and environmentally-friendly agricultural techniques and technology. Increasing awareness exists regarding the potential of ecological and sustainable agricultural practices to counteract the decreasing trend in crop output and contribute to environmental preservation (Wani *et al.,* 1995).

Due to the fragile and dynamic nature of soil, it requires regular maintenance and nourishment to ensure its sustained productivity and stability throughout time. Mere reliance on chemical fertilisers is inadequate for preventing the depletion of organic matter and nutrient mining. It is crucial to also incorporate organic sources of plant nutrients, such as cow dung, chicken manure, bioslurry, compost, green manure, and other organic sources (Prado *et al.,* 2022; Ding *et al.,* 2021; Vanotti *et al.,* 2020; Hammerschmiedt *et al.,* 2021). Organic manures, such as crop wastes, animal manure, and green manure, directly impact the amount of organic matter in the soil. This can improve the physical, chemical, and fertility properties of the soil, increase microbial activity, and reduce metal toxicity by forming complexes with metals in contaminated soil (Escobar and Hue, 2008). Soil organic matter mineralization results in the release of significant quantities of nitrogen (N), phosphorus (P), and sulphur (S), along with a lesser number of micronutrients (Rahman *et al.,* 2013). Including organic sources of plant nutrients such as manures and composts should be seen as a feasible and sustainable method. This is because environmentally friendly methods can replenish soil fertility, improve crop yield, and safeguard the environment from human-induced harm (Wani *et al.,* 1995). The implementation of a smart integration of manures and fertilizers can potentially lead to the improvement and maintenance of crop output and soil fertility.

In order to enhance soil fertility and optimise crop yield over an extended period, it is necessary to use a systematic approach that involves the consistent application of organic matter and a well-balanced management of both organic and inorganic fertilizers. The effective handling of organic waste materials has become crucial in the quest for sustainable farming operations. Concentrated organic manures are particularly promising among these materials because they contain high levels of nutrients, especially sulphur and phosphorus. Nevertheless, there is a lack of research on the processes of S and P mineralization in these manures when exposed to anaerobic environments. Gaining knowledge about the mechanisms that control the release and accessibility of these vital nutrients is key for optimising strategies for managing nutrients and reducing environmental concerns linked to their incorrect disposal (Niyungeko *et al.,* 2020; Lisowska *et al.,* 2022).

Anaerobic conditions, which are defined by a limited presence of oxygen, are commonly seen in many agricultural environments, such as waterlogged soils and anaerobic digesters. In such circumstances, the mechanisms controlling the mineralization of S and P display noticeable patterns in contrast to aerobic environments. Anaerobic microbial communities facilitate the breakdown of organic matter, resulting in the liberation of soluble forms of sulphur and phosphorus due to microbial activity and the destruction of organic matter (Kacprzak *et al.,* 2023; Rigby *et al.,* 2023). Nevertheless, the degree and speed of mineralization can significantly differ based on variables such as substrate composition, temperature, pH, and microbial community structure.

Mineralization of soil organic matter results in the release of significant quantities of macronutrients (Rahman *et al.,* 2013). This process occurs gradually, which promotes a decrease in nutrient loss and enhances plant uptake. Manures gradually and consistently release nutrients, which remain accessible to plants for an extended period without substantial depletion. The primary biogeochemical process that enhances soil fertility and improves crop output is the mineralization of carbon (C) and nitrogen (N) derived from manures (Cai *et al.,* 2016). Accurate measurements of nutrient mineralization can efficiently estimate the appropriate amount of manure without compromising output or raising the risk of contamination. The rate at which organic materials undergo mineralization and release the nutrients they contain impacts their efficacy as a fertiliser (Cai *et al.,* 2016). The quantity of manure to be added to the soil is governed by its composition, the nutrient availability in the soil, the crop being cultivated, and the prevailing environmental circumstances (Eghball *et al.,* 2008). To effectively use dung as a fertiliser source, it is crucial to comprehend the mineralization rate in real-world conditions. The process of organic material decomposition is facilitated by specific meteorological conditions, particularly elevated temperatures, which are common in Bangladesh for most of the year, together with frequent and intensive soil cultivation practices. It is essential to comprehend the mineralization of nutrient components in the soil when using organic manure as a nutrient source in order to predict their availability (Moharana *et al.,* 2015). The quantity of nutrients released into the soil for the initial crop may be determined by utilising mineralization data, and the lasting impacts of organic nutrient sources applied to the subsequent crop can be easily assessed. The utilisation of different types of organic manures affects the availability of nutrients and requires careful management to optimise nutrient release and align with the requirements of the crops. It is crucial to determine the rate of net mineralization of compost in soil in order to optimise the usage of compost and supplement some of the chemical fertilisers needed throughout the plant growth phase (Hadas and Portnoy, 1994). Therefore, it is crucial to comprehend the mineralization process and nutrient accessibility in different organic manures to prevent nutrient deficiency, sustain optimal soil fertility, and enhance crop production through integrated nutrient management. This approach will decrease reliance on inorganic fertilisers and contribute to environmental conservation.

Phosphorus is an essential nutrient that plays a crucial role in plant growth and productivity by participating in several metabolic and structural processes, including photosynthesis, respiration, and protein synthesis. In numerous areas, the limited availability of phosphorus can lead to persistent shortages of this essential nutrient in the soil, which in turn hampers agricultural productivity (De la Fuente *et al.,* 2013; Jensen *et al.,* 2023). Once more, increasing the application of P fertiliser in certain agricultural soils leads to a larger amount of run-off, which can contribute to eutrophication in aquatic habitats. When organic matter is added to soils, the process of mineralization fulfils a significant portion of the plant's phosphorus requirement. The rate of phosphorus mineralization is influenced by various factors such as season, climate, soil organic matter, soil depth, and the C/P ratio of organic matter (Jalali *et al.* 2014). Many biogeochemical properties, such as soil moisture, organic matter, and clay content, significantly influence the distribution and movement of phosphorus in soils (Xiao *et al.* 2012). Soils that have an excessive amount of phosphorus (P) are susceptible to the process of leaching and run-off, as noted by Carpenter and Bennett (2011).

S is a vital element for plants as it plays a crucial role in the creation of chlorophyll and protein synthesis. Insufficient levels of sulphur can lead to adverse metabolic and visual effects. Organic S mineralization is regarded a vital source of sulphur for plants, as more than 95% of the total sulphur obtained from manures, crop wastes, and fertilisers occurs in organic form (Reddy *et al.,* 2001; Ghani *et al.,* 2001). The process of S mineralization is influenced by factors such as biological activity, the types of organic compounds present, and the physical and chemical features of the soil (Islam and Dick, 1998). The release kinetics of P and S in different soils after mineralization from various types of manures has not been extensively investigated in Bangladesh. Currently, there is insufficient evidence available regarding the conversion of various organic sources of these nutrients in soils under both aerobic and anaerobic circumstances (Risberg *et al.,* 2017; Sakadevan *et al.,* 1993). This study focused on the mineralization capacity of manures, allowing us to investigate the timing and patterns of P and S release in soils following manure application. Additionally, we assessed the suitability of manures for this purpose. The objective of this study was to examine the rate at which P and S are released in soils treated with various organic manures that had different moisture levels over a period of time. The aim was to determine if these manures could serve as a natural source of nutrients and as a substitute for synthetic fertilisers in our agricultural practices.

Concentrated organic manures, such as animal slurries, sewage sludge, and composted organic wastes, are important fertiliser sources for crop production. These materials provide a sustainable substitute for chemical fertilisers and also contribute to enhancing soil fertility and structure. Nevertheless, the utilisation of these applications can present difficulties, namely regarding the accessibility of nutrients and the influence on the environment. S and P, although necessary for the growth and development of plants, can undergo intricate changes within the soil-plant system, which are influenced by a variety of living and non-living elements. A comprehensive study on the release kinetics of P and S in diverse soils after mineralization from various types of manures is still lacking in Bangladesh. Researching the mineralization of S and P in Bangladesh is crucial due to the significant role these nutrients play in agriculture, which is a cornerstone of the country's economy. S and P are essential for plant growth, impacting crop yield and quality (Schott *et al.,* 2023; Pagliari, *et al.*, 2020). Understanding their mineralization can help optimize fertilizer use, reducing costs for farmers and minimizing environmental pollution. Additionally, many regions in Bangladesh suffer from soil nutrient depletion; studying these processes can aid in soil fertility management and sustainable farming practices. This research is also vital for addressing food security, as improved nutrient management can lead to more stable and increased food production. Finally, it can inform policy decisions regarding agricultural practices and environmental conservation, ensuring the long-term health of both the agricultural sector and natural ecosystems. Currently, there is insufficient data regarding the conversion of various organic sources of these nutrients in anaerobic soil conditions. Considering these views, this experiment was conducted-

I. To know the release kinetics of P and S in soils from different organic manures and

II. To assessed release of pH and EC content in soils from different organic manures

CHAPTER II

REVIEW OF LITERATURE

The application of organic manures, such as compost and animal slurries, is a common practice in agriculture to improve soil fertility and crop yields. These manures contain significant amounts of N and S, but their availability for plant uptake depends on the process of mineralization. Mineralization transforms organically bound N and S into inorganic forms, like ammonium (NH_4^+) and sulfate (SO_4^{2-}), which plants can readily utilize. Understanding how manure mineralization occurs under anaerobic conditions, where oxygen is limited, is crucial for optimizing nutrient management strategies.

Islam *et al.*, (2021) conducted a study to evaluate the mineralization patterns of various manures viz. cow dung (CD), cow dung slurry (CDSL), trichocompost (TC), vermicompost (VC), poultry manure (PM), poultry manure slurry (PMSL), and mungbean residues (MR) to establish their efficiency in releasing nutrients under aerobic (field capacity) and anaerobic (waterlogging) conditions. The mineralization of carbon (C) and nitrogen (N) ranged from 11.2 to 100.1% higher under aerobic conditions rather than anaerobic ones according to their report. They found that C mineralization was 45.8 to 498.1% higher in an amount from mungbean residues under both moisture conditions. For N release, mungbean residues and poultry manure exerted maximum amounts in anaerobic and aerobic scenarios, respectively. However, they got the rate of C and N mineralization was faster in trichocompost compared to other manures in both moisture conditions. Although trichocompost was 1.4 to 37.7% more efficient in terms of rapidity of mineralization, mungbean residues and poultry manure performed better concerning the quantity of nutrient release and soil fertility improvement. poultry manure had 22–24% higher N mineralization potential than poultry manure slurry while cow dung slurry had 46–56% higher N mineralization potential than Cow Dung according to their findings. In fine they concluded that the C and N mineralization in soil was greater under aerobic conditions compared to what occurred in the anaerobic context.

Rawal *et al.,* (2021) conducted a study to study the effects of phosphorus levels on mineralization of phosphorus(P) and potassium(K)under three soil types in laboratory conditions at the National Soil Science Research Center in Nepal. Two factors were evaluated on three soil types (silty clay loam, loam, and sandy loam) with four phosphorus levels: 0, 25, 50, and 75 kg P_2O_5 ha^{-1}. Five incubation periods (1, 30, 60, 90, and 120 d after incubation) were replicated three times with total of 180 experimental units. They found that the P and K mineralization patterns varied with soil types and P levels, with higher fluctuation of P content in silty clay loam soil as compared with loam and sandy loam soil. Besides, Phosphorus concentration with application of 25 kg, 50 kg, and 75 kg P_2O_5 ha^{-1} after 120 d of incubation were 95.6, 112.2, and 116.6 mg kg^{-1}, respectively, which was 19.65% (25 kg P_2O_5 ha^{-1}) to 45.93% (75 kg P_2O_5 ha^{-1}) higher than control. There were four stages of mineralization-immobilization turnover of Olsen-P and available K: rapid declining trend up to 30 d, slow rise up to 60 d, rapid mineralization up to 90 d, and then slows down up to 120 d. On average, rapid reduction in soil pH from 6.60 to 5.42 was observed within 120 d of incubation, according to their reports.

Sultana *et al.,* (2021) stated that some organic amendments enhance nutrient level of marketed municipal solid waste (MSW) compost for its potential use as fertilizer for growing crops in alluvial soils. For that they prepared three types of amended compost by mixing 20% mustard oil cake (MOC), and 30% poultry manure (PM) or cow dung (CD) or sugarcane press mud (SPM) with 50% MSW compost. The nitrogen (N), phosphorus (P) and sulphur (S) mineralization study was done by them in soil treated with three amended and one unamended compost through an incubation experiment at a temperature of 25 ± 1°C for 82 days under aerobic (field capacity) and anaerobic (submerged) conditions. They found that the soil NO_3--N content was 2-3 times higher in aerobic condition than in anaerobic condition, while the NH_4 +-N was higher in anaerobic soils. The kinetic model reveals that poultry manure and sugarcane press mud had higher capability to supply N for use by the crops. The P release was the highest at day 15 with three-time higher availability in anaerobic condition according to their reports. they also recorded that The S mineralization in soil was higher in field capacity than in submerged condition. They finally concluded that compost mixture comprising MSW, MOC and SPM in a ratio of 5:2:3 demonstrated the highest cumulative N, P and S mineralization in both aerobic and anaerobic conditions. The N and S availability decreased while the P availability increased in submerged soils which result has fertilizer management implications for wet land rice crop.

Islam *et al.,* (2021) stated that a good understanding of nutrient release from manure or compost after application through mineralization is important to assure meeting the nutrient demand of crops, to secure timely fertilizer application and to enhance nutrient use efficiency. So, they conducted a study to evaluate phosphorus (P) and sulphur (S) release patterns from different types of manures viz. cow dung, cow dung slurry, tricho-compost, vermicompost, poultry manure, poultry manure slurry and mungbean residues. Their mineralization study was performed under aerobic (field capacity) and anaerobic (waterlogging) conditions for 180 days at 25 ± 1 ◦C in the laboratory. They showed that the release of P and S was the highest values within 75–180 and 75–150 days, respectively, and was always higher in aerobic conditions than in anaerobic conditions. The first-order kinetic cumulative model was a good fit for mineralization, which was significantly influenced by manure type, soil moisture level and incubation period, according to their reports. Poultry manure slurry exerted the highest P and S release under both moisture conditions. in fine, they stated that both slurries showed higher potential mineralization, with a lower rate constant for these elements compared to that in their manure states.

Research by (Gong *et al.,* 2021) compared the release of N and S from various digested manures and found that the rate and extent of mineralization differed depending on the manure type. Several studies have investigated the mineralization of N and S from organic manures in anaerobic environments. They observed a higher net N mineralization (up to 71.3% of applied N) from digested alfalfa compared to other manures, while S mineralization was generally lower across all treatments, ranging from 1.75% to 26.0%. This highlights the variability in nutrient release based on the initial composition of the manure.

An incubation experiment was conducted by Zamil *et al.,* 2015 to find out the decomposition pattern of organic manures and release pattern of available nitrogen (N) [ammonium nitrogen (NH_4-N) and nitrated nitrogen (NO_3-N)] and phosphorus (P) from the manures. They used poultry manure (CS-PM), deep litter system poultry manure (DLS-PM), cow-dung (CD) and bio-gas slurry (BS) in this experiment. Soil was amended by them with these manures @ 1 g 50 g^{-1} soil. Microbial respiration (CO_2 evolution), NH_4-N, NO3-N and available P were monitored by them over 30days at different day intervals. After 30 days of incubation, 24.59, 22.46, 20.52 and 18.61% of the added C were decomposed from CS-PM, DLS-PM, BS and CD amended soil, respectively. They recorded that N mineralization was highest at day 5 in CS-PM, DLS-PM and BS amended soil but in CD at day 10. All the manures showed marked immobilization after mineralization. Finally, net N mineralization was 118.03, 84.28, 69.80 and 52.13 μg N g^{-1} soil in CS-PM, DLS-PM, BS and CD amended soil, respectively. Application of animal residues caused significant increase in P mineralization according to their report. They concluded that Net P mineralization were 47.21 μg, 32.79 μg, 19.70 μg and 15.63 μg P g^{-1} soil after 30 days of incubation in CS-PM, DLS-PM, BS and CD amended soil, respectively.

(Li *et al.,* 2020) reported that poultry manure slurry exhibited the highest level of P and S release compared to other manure types in their study. The type of organic manure also influences the dynamics of N and S mineralization under anaerobic conditions. This suggests that the organic composition and degradability of the manure can significantly impact the mineralization process.

Haque *et al.*, (2015) conducted an experiment to examine the nitrogen (N) mineralization pattern of bioslurry and other manures under aerobic and anaerobic soil conditions. Two bioslurries (cow dung and poultry manure) and their original manures (cow dung and poultry manure) @ 3, 5, 10 and 20 t ha^{-1}, respectively, were thoroughly mixed with soil and incubated in aerobic and anaerobic moisture condition for 12 weeks and available N (both NH_{4+}-N and NO_3--N) was measured by them through steam distillation method. They recorded that the NO_3--N was the dominant form of inorganic N in aerobic soil, whereas, NH4+-N dominated under anaerobic soil condition. When highest cumulative total available N mineralization among the manures at 3, 5, 10 and 20 t ha^{-1} rate was considered after 12 weeks of incubation, the N mineralization was 5.0, 5.5, 6.8 and 4.3 times higher, respectively, in aerobic condition over anaerobic condition. They also found that, cow dung bioslurry and poultry manure bioslurry had very closer percentage of N mineralization under aerobic condition and was much higher compared to their original manure (cow dung and poultry manure, respectively). With the increase of the rate of manure application, total available N release was increased but percent N release was rather decreased irrespective of the types of manure and soil moisture contents according to their findings. In conclusion, they reported that the application of bioslurries in parallel with their original manures (cowdung and poultry manure) in soils are, therefore, should be considered and recommended to increase N fertility in soil.

Wyngaard and Cabrera, (2015) conducted a study to measure the N, S, and P mineralization potentials of soils amended with inorganic fertilizer (IF) or poultry litter

(PL), and to evaluate different methods to estimate mineralization. The N mineralization potential (N_o) measured by them in aerobic incubations (24 wk) was 1.8 to 233.1 g N kg^{-1} greater in PL- than in IF-amended soils, depending on the type of soil. They found S mineralization potential (So) was 0 to 21.2 g S kg^{-1} greater in PL-amended soils than in IF-amended soils, depending on the type of soil. The 7-d aerobic incubation, the extraction with $NaHCO_3$, and Nan were good estimators of So (r2=0.85, 0.85 and 0.99, respectively). They also got the increase in No and So observed in PL- relative to IF-amended soils was closely associated with the soil clay content (r2> 0.90). The cumulative organic P mineralized in a 13-d incubation experiment, measured by them through isotopic dilution method, varied between 9.7 and 90.7 mg P kg^{-1}, and was greater or equal in PL- than in IF-amended soils, depending on the type of soil. The mineralized P was strongly associated with the organic P content in the coarse fraction of the soil (> 53 µm) (r2=0.92), but not with any other measured labile P pool in the soil. Finally, they suggested that the quantification of Po in the CF as well as the measurement of respiration corrected by the CT : Po ratio of the CF are promising non isotopic indicators of Po mineralization rates.

Schmidt *et al.,* (2015) observed that the presence of sulfate can stimulate the mineralization of organic nitrogen by providing an additional electron acceptor for microbial metabolism under anaerobic conditions. The mineralization of nitrogen and sulfur is often interconnected. Sulfate-reducing bacteria can utilize organic nitrogen compounds as a source of energy, linking the cycles of these two essential nutrients.

Wiederhold *et al.,* 2014 found sulfate-reducing bacteria convert sulfate to hydrogen sulfide (H_2S) in anaerobic environments. However, in the presence of organic manures, the process might lead to the production of intermediate sulfur compounds before complete reduction.

Studies by Luo *et al.* (2014) have shown that the rate of ammonification is influenced by the Cnratio of the organic material and the prevailing redox conditions. Anaerobic conditions significantly alter the microbial processes responsible for nitrogen mineralization. In the absence of oxygen, facultative and obligate anaerobes become the primary decomposers. These microorganisms convert organic nitrogen into ammonium (NH_4+), a process known as ammonification.

Wang *et al.,* (2013) shown that temperature and moisture significantly affect anaerobic N mineralization. High temperatures can accelerate microbial activity, while optimal moisture levels are necessary to maintain anaerobic conditions.

Murugan and Swarnam, (2013) carried out a laboratory incubation experiment to determine the nitrogen release pattern from vermicompost (V.C), poultry manure (P.M), neem, inorganic fertilizer (I.O) and its combinations applied to an acid soil at two different rates. they recorded that the cumulative nitrogen mineralization was significantly higher throughout the incubation period for I.O, V. C+P.M and I.O+V.C while it was two weeks after incubation for V.C and V.C+Neem due to the inhibitory effect of neem on nitrification. Their results indicated a significant increase in the rate of N mineralization in the first one week in which the highest rate of 3.36 mg N day^{-1} was observed for inorganic fertilizer and thereafter it slowed down. V.C followed by V.C+Neem recorded higher rate of N mineralization of 0.24 and 0.23 mg day^{-1} respectively, from 48th days after incubation. they also recorded that the V.C+Neem at 120 kg N equivalent ha^{-1} had the highest ammonia content of 42.1% to total available N while V.C+P.M recorded higher nitrate content of 82.3% at the end of the incubation period. Positive correlation between initial nitrogen and total mineralized N from the manures and fertilizers (R2 = 0.563) was observed by them. Furthermore, addition of organic manures resulted in increase in soil pH whereas inorganic fertilizer showed a slight decrease (5.73) than control (5.78), according to their findings.

Soropa *et al.,* (2012) conducted a study to determine phosphorus (P) mineralisation and agronomic potential of pelletized phosphate blends (PPB) enhanced cattle manure using incubation and green house experiments for two soils in Zimbabwe. Under incubation, the rate of P mineralization for untreated and PPB treated manures was determined by them using the Bray 1 method on destructive samples (2 g sub-sample) of the soils collected 3, 7, 14, 28 and 42 days after incubation had commenced. A greenhouse experiment was established by them to test for direct and residual effect of 10 and 20 t ha-1 of untreated and PPB enhanced cattle manure on P uptake and maize growth. Their results of the incubation study showed a significant decrease in the amount of P release into solution for the two soils. The greenhouse results showed no significant ($p < 0.05$) difference in the maize biomass yield at 5 WACE between the untreated and PPB enhanced manures from both soils. However, the maize P uptake differs with soils across all the treatments. They got there was no significant ($p < 0.05$) difference in the available P in the biomass harvested among all the treatments regardless of soil type used.

Möller and Müller (2012) reported that digested slurry contains a higher proportion of readily available nitrogen (NH_4+) compared to undigested manure, highlighting the efficiency of anaerobic digestion in enhancing nitrogen mineralization. In biogas digesters, where anaerobic conditions are maintained to produce methane, nitrogen mineralization is a critical step.

Azeez and Averbeke, 2010 conducted a laboratory incubation for 120 days to study the fate of phosphorus in poultry (PM), cattle (CM) and goat manures (GM). They stated that the Phosphorus mineralized from manure was dependent on total P, Al and Fe content and manures improved P availability in the order: PM > CM > GM; however, the highest amount of P was fixed or immobilized between 10 and 70 days of incubating with CM and GM. Fixation and immobilization of mineralized P from poultry manure was negligible probably due to the high total P and the low amount of Al and Fe according to their report. Generally, manure application reduced the ability of the soil to fix P. More than 90% of the manure P was either immobilized or fixed by the soil observed by them. The relationship between the amount of P released and time was cubic. They concluded that the improvement of the C:P ratio of CM and GM would be an option to enhance their agronomic use as fertilizer P source.

Eriksen, 2009 found sulfur in manures exists in both organic and inorganic forms. Organic sulfur must be mineralized to sulfate (SO4^2-) before it becomes available to plants. This process is mediated by anaerobic bacteria such as sulfate-reducing bacteria (SRB).

Marcato *et al.,* (2009) studied the changes in pig slurry organic matter (OM) during anaerobic digestion (AD) in a reactor to characterize OM evolution through AD. OM maturity and stability were evaluated by them through using different biological and physico-chemical methods. Germination and growth chamber experiments revealed a higher maturity of digested slurry (DS) than raw slurry (RS). Soil incubations showed that DS was more stable than RS with a C-mineralization of 12.0 gCO_2-C100 g 1Corg after 49 days as compared to 17.6 g CO2 C100g 1Corg. Biochemical fractionation showed a relative increase in stable compounds such as hemicellulose-like and lignin-like molecules according to their reports. Fourier-transform infrared spectroscopy showed some changes in the chemical structures of OM with a reduction in the aliphatic chain, lipid and poly saccharide levels. Besides, a comparison between the evolution of OM during AD and the first weeks of a composting process showed almost identical changes. Finally, they observed stability in DS was mainly due to the biodegradation of the most labile compounds.

Reddy and DeLaune (2008) demonstrated that high-lignin content in organic residues slows down the decomposition and subsequent nitrogen release under anaerobic conditions due to reduced microbial activity. The quality and composition of organic matter play a pivotal role in nitrogen mineralization.

Dawi, (2006) conducted a field experiment (for 16 weeks) was carried in western Omdurman, with a soil vulnerable to wind erosion, to monitor decomposition and nutrient release from residues of Mesquite (Prosopis spp), Mahogany (*Khaya senegalensis*) and Neem (*Azadirachta indica*). Fresh leaves litters were placed by them inside litterbags and buried into the top 25cm depth of an Aridisol subjected to wind erosion. They draw samples at intervals of 1, 2, 4, 6, 8, 10, 12, 14, and 16 weeks and analysed to determine remaining dry matter weight, N, P, K, Ca, Mg, and C. Their result showed that the neem decomposed significantly faster than both Mesquite and Mahogany with rate constant (k) of 0.44 week^{-1} (Neem) and 0.12 week^{-1} for both Mesquite and Mahogany. Also, they showed that C/N ratio is not a good quality indicator in decomposition. However, content of lignin and cellulose were best indicators, especially for Neem residues reported by them. All litters were found good sources of K, especially in sandy soils which low in K, as 80% of the initial content of this mineral was released in the first 2 weeks according to their findings. They finally suggested that, Mesquite and Neem constituted readily available source of N, and they could be suitable for short-term nutrient correction.

Yang *et al.*, (2005) found that the rate of S mineralization depends on the type of manure and its sulfur content. For instance, manures with high organic sulfur content can potentially release more SO_4^2- under anaerobic conditions.

Hoffman *et al.*, 2005 stated that N and S mineralization in manures under anaerobic conditions helps predict nutrient availability for crops, particularly in waterlogged or flooded soils where anaerobic conditions prevail.

Chantigny *et al.,* (2004) recorded that the proper management of manure application timing and method can optimize N and S availability, enhancing soil fertility while minimizing environmental risks such as gaseous emissions and nutrient leaching.

Chapuis-Lardy *et al.,* (2003) stated that cattle slurry manure applied to land increases the risk of phosphorus (P) movement to surface waters, which may lead to eutrophication. The water-extractable fraction of P in slurry manure is correlated with P concentration in runoff from soils amended with slurry manure, and thus is an effective indicator of environmental P loss. For that they evaluated the water-extractable P (WEP) and readily soluble P (RSP; i.e., P extractable in a single water extract) contents in slurry manure from nine farms. On some farms, the additive Euromestmix® (MX) is used by them to complex N-compounds in the slurry manure, but the effect of MX on Pin the slurry manure is not known. They also focused on methodological factors affecting the measurement of P in slurry manure. Drying the slurry manure before analysis decreased, WE P and RS P contents. Dilution of slurry manure by varying the dry matter-to-distilled water ratio increased the water-extractable fractions according to their reports. Analysis of calcium and magnesium contents in water showed that these minerals are involved in the release of P in water. They got that total RSP content of slurry manures from the nine farms ranged from 1.83 to 4.06 mg P per g dry matter. They concluded that a substantial portion of total P in the slurry manure occurred in the water-extractable (46-71%) and the readily soluble P fractions (24-51%).

Tisdale *et al.,* (1993) stated that organic N in manures is converted to ammonium (NH_4+) through a series of microbial-mediated processes under anaerobic conditions. This involves the breakdown of complex organic molecules by anaerobic bacteria, which is slower compared to aerobic conditions.

Sommer and Hutchings (2001) suggested that optimizing anaerobic digestion processes and managing waterlogged soils can enhance the availability of N and S from organic manures, reducing the need for synthetic fertilizers and promoting sustainable agriculture. Understanding the mechanisms and factors influencing N and S mineralization under anaerobic conditions can inform agricultural practices aimed at improving nutrient management.

Chadwick *et al.,* (2000) stated that different types of organic manures, such as cattle manure, poultry litter, and pig slurry, have varied nitrogen content and composition, affecting the rate and extent of mineralization. For instance, poultry litter often results in higher NH_4+ production due to its high nitrogen content.

Hadas & Portnoy, (1994) found laboratory incubations provide controlled conditions to study N mineralization. Researchers have used sealed containers to create anaerobic environments and monitored NH_4+ production over time

Burford & Bremner, (1975) stated that the mineralization of N and S can be interdependent. High ammonium concentrations can inhibit sulfate reduction due to competitive inhibition of microbial processes.

CHAPTER II

MATERIALS AND METHODS

2.1. Soil Sample Collection and Preparation

The soils samples used for this study were collected at a depth of 0–15 cm from the Field Laboratory of Soil Science Department, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur-5200. The soil sampling site lies between located in between 25°10' and 26°04' north latitudes and in between 88°23' and 89°18' east longitude, and the experimental soil was characterized as Non-Calcareous Grey of Piedmont plain and Tista Floodplain soil under the agro-ecological region of the AEZ (Old Himalayan Piedmont Plain) (FAO, 1988 and UNDP, 1988). Soil sampling was done from different areas where crop plants were usually grown under no experimental trial and thoroughly mixed to make composite samples. Each composite sample contained six simple soil samples. Composite samples were transported to the laboratory and air dried on a brown paper. After air dried, soil samples were crushed and passed through sieves with a 2 mm mesh in order to remove unwanted materials such as crop debris, brick pieces, stone pieces, and so on. Sieved soils were kept in polyethylene bags and incubated for 21 days under anaerobic conditions at 25◦C temperature. All soil samples were stored in a dry and cool place prior to incubation study.

Fig 01: Photographs during soil collection and preparation

2.2. Analysis of Initial Soil Samples

The initial soil samples were used to determine the physicochemical properties of the soil including textural class, bulk density, cation exchange capacity (CEC), soil pH, organic carbon (OC), total N, exchangeable potassium (K), available P and available S (as presented in Table 1). Physicochemical properties were measured as they change with land use. The hydrometer method was employed to determine the particle size analysis and Marshall's Triangular Coordinates (USDA system) were used to determine the textural class of the soil. The bulk density of the soil was measured by the core sampler method. The pH of the samples was assessed in a soil : water ratio of 1:2.5 with a glass electrode pH meter. The CEC and OC were estimated by the sodium saturation method and the Walkley and Black method, respectively. Total N was determined by semi-micro Kjeldahl method, and available P was measured according to Olsen method. Analysis of exchangeable K was based on the NH_4OAc (1 N) extraction method at pH 7 with a flame photometer. Available S was assessed by a 0.15% extractant solution of CaCl2 following turbidity measurement with a spectrophotometer (Williams and Steinbergs, 1959). The water holding capacity of the soil was measured by the gravimetric method following standard protocol (Soil Testing Procedure Manual, 2008).

Fig 02: Photographs during analysis of initial soil sample

Table 3.1: General (physical and chemical) characteristics of the soil.

Soil Characteristics	Value
Particle size distribution (USDA system)	
% Sand (0.2–0.05 mm)	48%
% Silt (0.05–0.002 mm)	28%
% Clay (<0.002 mm)	24%
EC	0.14
Textural class	Loamy soil
Bulk density (g cm−3)	1.31
Organic C (%)	.54%
Cation exchange capacity (me Na/10g)	5
pH	5.2
Total N (%)	0.14
Available P (mg kg^{-1})	
Exchangeable K (cmol kg^{-1})	0.06
Available S (mg kg^{-1})	24-74

2.3. Collection of Different Manures and Determination of Their Chemical Composition

The present investigation utilized seven categories of organic fertilizers viz. Tea Waste (TW), Banana Peel (BP), Egg Shell (ES), Mustard Oil Cake (MOC), Fish Meal (FM) and Biochar Enrich Organic Fertilizer (BEOF). Tea Waste were collected from a tea stall in Basherhat, Dinajpur and then prepared in the laboratory of the Department of Soil Science in Hajee Mohammad Danesh Science and Technology University. Peels of banana were collected from a fruit shop of Basherhat, Dinajpur and prepared for using in this research. Egg Shell were collected from different houses of HSTU, Mustard Oil Cake and Fish Meal were collected from a fertilizer shop, BEOF were collected from an organic fertilizer shop of Basherhat, Dinajpur. After collection of all these materials, fertilizers were dried properly and blended into a blender machine. After blending properly, fertilizers were ready for using into the research. Total P and S in initial manure samples were measured by colorimetric and turbidimetric methods, respectively, with a spectrophotometer (Yamakawa, 1992), after digestion with di-acid mixture (HNO_3–$HClO_4$ 3:1) as suggested by Piper (Piper, 1966).

Fig 03: Photographs during Collection of Different Manures and Determination of Their Chemical Composition

2.4. Experimental Setup

The mineralization of P and S in different categories of manures was assessed under controlled conditions anaerobic based on the destructive sampling procedure. A series of plastic pots were filled with 50g air-dried soil. The air-dried manures (TW, BP, ES, MOC, FM and BEOF) were mixed with soil at 20 ton per ha or 20 Mg per ha (0.5 g manure was mixed with 50 g soil). The sets without adding organic manures served as control treatments. The moisture status of both manure-amended and unamended soil was maintained at field capacity (25% moisture; 50% pore space filled with water). The containers were placed in an incubation room and incubated for the duration of 90 days at 25◦C temperature. Three replications were used for each treatment.

Fig 04: Photographs during experimental setup

2.5. Organic Fertilizer Incubation in Soil

For measuring P and S mineralization in anaerobic incubation of dry soil whereas plastic cups with an inner diameter of 7 cm and height of 12 cm were used. All the containers were placed in a dark place for incubation at room temperature (25 ± 2 ˚C) for the period of 90 days. Para film was used to wrap the pots to reduce subsequent water loss, and then the pots were shifted to an air-conditioned room with a proper aeration system. The soil moisture content was recorded at 15 days intervals. The weight reduction in terms of evaporation was diminished by supplying adequate quantity of deionized water and properly mixed with soil to achieve specific moisture content (soil saturation and field capacity of soil). The total number plastic cups filled up for this incubation. The destructive sampling method was followed in this experiment. The 1st sampling was performed at just the next day of incubation, and this assessment was utilized as the preliminary content of soils. The preliminary weights of the cups along with soil were also measured.

Fig 05: Incubation period

2.6. Analysis of Soil Samples after Manure Application

Soil sampling was done from each replicate through destructive methods by taking out soil from every cup at 1, 15, 30, 45, 60, 75and 90, days after the application of organic manure. The P availability in soil was determined by the $NaHCO_3$ (0.5 M) extraction method at pH 8.5 5 (Olsen, et al., 1954). A $CaCl_2$ extractant solution (0.15%) was used to quantify available S in soil followed by measurement of the turbidity with a spectrophotometer. The obtained data were adjusted for moisture content and presented based on an oven-dry basis.

Fig 06: Photographs during analysis of soil sample

2.7. Statistical Analysis

The data were subjected to analysis of variance (ANOVA) technique using Statistix 10 software package by repeated measures design. Mineralization kinetics were determined using Sigma-Plot 14.0 software. For the repeated measure analysis, treatments were taken as the between-subject factor and time as the within-subject factor. Non-linear regression was used to fit the mineralization data into first-order kinetic model using the Levenberg– Marquardt algorithm. Post hoc tests were performed to separate differences among the modelled value of potentially mineralized P, P0, S, S0 and rate constant k using the Tukey–Kramer multiple comparison. All statistical analyses were considered significant at $P < 0.05$, unless otherwise mentioned.

CHAPTER IV

RESULTS AND DISCUSSION

Results are presented and discussed in this Chapter. Data are shown in various tables and figures.

4.1 Effect of different treatments on S (%) release content of the soil sample

The release of S content showed significant variation on different date among the samples due to different treatments. The T_1 treatment (mustard oil cake) recorded the highest release of sulfur content under anaerobic conditions (26.76%) on Day 1, with the T_2 treatment (fish meal) following closely at 24.59%. T_3 (bone meal) recorded the third highest release of sulfur content under anaerobic conditions (20.32%) among the treatments applied statistically alike with all other treatments except T_6. However, the T_6 (control) and T_4 (Biochar enriches organic fertilizer), T_5 (vermicompost) treatments recorded the lowest release of sulfur content (12.30, 17.15 and 18.11%, respectively). On Day 15, the T_1 treatment (mustard oil cake) and the T_2 treatment (fish meal) had the highest release of sulfur levels (32.77% and 29.11%, respectively). T_3 (bone meal) exhibited the second highest concentration of released sulfur, measuring 20.11%. Nevertheless, the T_6 (control) treatments exhibited the lowest release of sulfur level (10.62%). On Day 30, the T_1 treatment (mustard oil cake) and the T_2 treatment (fish meal) had the highest release of sulfur levels (42.18% and 41.90%, respectively) under anaerobic conditions. Even so, the T_6 (control) treatments released the least sulfur (16.72%). On the 45th day, the T_1 treatment (mustard oil cake) released the highest levels of sulfur (24.89%). However, the T_6 (control) treatments showed the lowest sulfur release (12.59%), which is statistically dissimilar to all the treatments under anaerobic conditions. On the 60th day, the T_1 treatment (mustard oil cake) exhibited the greatest release of sulfur levels (91.99%) which is statistically similar to T_2 (fish meal) treatment (91.02) under anaerobic conditions. However, the T_6 (control) treatments released the lowest amount of sulfur (72.71%), statistically equivalent to the T_4 (Biochar enriches organic fertilizer) and T_5 (vermicompost) treatment under anaerobic conditions. On the 75th day, the T_1 treatment released the highest levels of sulfur (102.98%). T_2 had the second-highest "S" release (101.32%) followed by T_3 (bone meal). However, the T_6 (control) treatments showed the lowest sulfur release (80.08%), statistically similar to most of the other treatments under anaerobic conditions. On the 90th day, the T_1 treatment (mustard oil cake) exhibited the most elevated amounts of sulfur (84.76%) which is statistically alike to T_2 (79.85) treatments. However, the T_6 (control) treatments exhibited the lowest sulfur release (60.95%) under anaerobic conditions (Table 4.1).

S release after mineralization in modified soils, according to some studies (Reddy *et al.,* 2001; Islam *et al.,* 1998), is dependent on the S concentration of the decomposing materials (Islam *et al.,* 2021). The sulfur concentration in decomposing materials varies due to differences in their original compositions and sources. Mustard oil cake, derived from mustard seeds, contains higher sulfur due to the presence of glucosinolates, which are sulfur-containing compounds. Fish meal, rich in protein, has a significant amount of sulfur from sulfur-containing amino acids like cysteine and methionine. S concentration release is maximum in mustard oil cake among the listed decomposing materials due to its high sulfur content. Mustard seeds naturally contain significant amounts of sulfur, which is retained in the oil cake after oil extraction. Additionally, the decomposition process of mustard oil cake is relatively rapid, leading to a quicker release of nutrients, including sulfur, into the soil.

Table 4.1: Effect of different treatments on Sulfur (%) content of the soil sample

Treatment	1 Day	15 Day	30 Day	45 Day	60 Day	75 Day
T_1	26.76 a	32.77 a	42.18 a	24.89 a	91.99 a	102.98 a
T_2	24.59 ab	29.11 a	41.90 a	18.89 b	91.02 ab	101.32 a
T_3	20.32 bc	20.11 b	32.45 b	17.31 b	84.05 bc	92.79 ab
T_4	18.11 cd	15.78 c	26.01 bc	17.07 b	80.08 cd	87.32 b
T_5	17.15 cd	15.69 c	24.79 c	15.86 bc	78.73 cd	86.75 b
T_6	12.30 d	10.62 d	16.72 d	12.59 c	72.71 d	80.08 b
LSD	6.14	3.85	6.86	4.26	7.67	13.03
Level of Significance	**	**	**	**	**	*

Here, mean with similar letter do not differ significantly

Here, T_1= Mustard oil Cake, T_2= Fish meal, T_3= Bone meal, T_4= Biochar enriches organic fertilizer, T_5= Vermicompost and T_6= control

4.2: Effect of different treatments on P (%) release content of the soil sample

The release of P content showed significant variation on different date among the samples due to different treatments. The T_1 treatment (mustard oil cake) recorded the highest release of P content (4.99%) on Day 1, statistically similar to all the treatments except control (T_6) treatment under anaerobic conditions. However, the T_6 (control) treatment recorded the lowest release of P content (3.44%) statistically similar to all the treatments except T_1 and T_2 treatments. On Day 15, the T_1 treatment (mustard oil cake) had the highest release of P levels (5.50) statistically similar to all the treatments except T_4 and T_6 under anaerobic conditions. Nevertheless, the T_6 (control) treatments exhibited the lowest release of P level (4.82%), which was statistically comparable to the all the treatments excluding T_1 and T_2. On Day 30, the T_1 treatment had the highest P release, with percentages (5.63%) statistically similar to T_2, T_3 and T_4 treatments. But, the T_6 (control) treatments released the least P (4.93%) statistically similar to all the treatments except T_1 treatment under anaerobic conditions. On the 45th day, all the treatment statistically showed alike result. However, the T_1 treatment released the highest levels of P (6.65%). However, the T_6 (control) treatments showed the lowest P release (5.71%), which is statistically similar to all the treatments. On the 60th day, all the all the treatment statistically showed similar result except control. The T_1 treatment, exhibited the greatest release of P levels (6.51%) under anaerobic conditions. However, the T_6 (control) treatments released the lowest amount of P (5.77%), statistically equivalent to the all without T_1 treatment. On the 75th day, the T_1 treatment released the highest levels of P (14.12%) followed by T_2 (14.04%) under anaerobic conditions. Rest of the treatment gave the same result except control treatment. However, the T_6 (control) treatments showed the lowest P release (12.82%), statistically similar to all except T_1 and T_2 treatment. On the 90th day, the T_1 treatment exhibited the most elevated amounts of P (20.24%) under anaerobic conditions. This value exhibits statistical significance compared to the values observed for the other treatments except T_5 and T_6 treatments. Nevertheless, the T_6 (control) treatments exhibited the lowest P release (18.06%) statistically similar to the T_5 treatment under anaerobic conditions (Table 4.2).

The release of phosphorus (P) is maximum from mustard oil cake among the mentioned organic manures under anaerobic conditions due to several factors. Firstly, mustard oil cake contains a higher proportion of phytate-P compared to bone meal, fish meal, biochar, and vermicompost. Under anaerobic conditions, the mineralization of organic phosphorus is limited, and phytate-P remains largely unavailable to plants. However, mustard oil cake also possesses enzymes like phytase that can slowly break down phytate-P, releasing inorganic phosphorus usable by plants even in anaerobic environments. This enzymatic breakdown is further enhanced by the microbial activity present in mustard oil cake during decomposition. According to Meena *et al.* 2021 a decreased concentration of P in the residue delays the mineralization process because the C-to-P ratio in the soil is too large for proper mineralization.

Table 4.2: Effect of different treatments on Phosphorus (%) content of the soil sample

Treatment	1 Day	15 Day	30 Day	45 Day	60 Day	75 Day
T_1	4.99 a	5.50 a	5.63 a	6.65 a	6.51 a	14.12 a
T_2	4.96 a	5.39 ab	5.38 ab	6.61 a	6.32 a	14.04 a
T_3	4.46 ab	5.28 abc	5.24 ab	6.56 a	6.30 ab	13.54 ab
T_4	4.31 ab	5.21 abc	5.05 b	6.48 a	6.26 ab	13.45 ab
T_5	4.18 ab	5.00 bc	5.01 b	6.40 a	6.22 ab	12.94 ab
T_6	3.44 b	4.82 c	4.93 b	5.71 a	5.77 b	12.82 b
LSD	1.28	0.49	0.58	0.96	0.53	1.20
Level of Significance	NS	NS	NS	NS	NS	NS

Here, mean with similar letter do not differ significantly

Here, T_1= Mustard oil Cake, T_2= Fish meal, T_3= Bone meal, T_4= Biochar enriches organic fertilizer, T_5= Vermicompost and T_6= control

4.3 Effect of different treatments on pH release content of the soil sample

The release of pH content showed significant variation on different date among the samples due to different treatments. The T_1 treatment and T_5 treatment recorded the highest release of pH content (6.73%) on Day 1, followed by all the treatments except T_3 treatment (bone meal) (6.57%). However, the T_3 (bone meal) treatments recorded the lowest release of pH content (36.57) followed by all the treatments except T_6 and T_5 treatments. On Day 15, the T_2 treatment and the T_1 treatment had the highest release of pH levels (6.67% and 6.60%, respectively). These values are statistically the same with the T_3 and T_6 treatments. Nevertheless, the T_4 treatments exhibited the lowest release of pH level (6.33%), which was statistically comparable to the T_6 treatment (Table 4.3). On Day 30, the T_1 treatment had the highest pH release (6.83%) which is statistically different from others. The T_2 treatment released the least amount of pH (6.27%) under anaerobic conditions. The rest of the treatments showed the statistically intermediate release of pH. On the 45th day, the T_2 treatment using fish meal released the highest levels of pH (6.77%) under anaerobic conditions. This is statistically similar to all other treatments except the control. However, the T_6 (control) treatments showed the lowest pH release (6.37%), which is statistically similar to all the treatments except T_2. On the 60th day, the T_6 treatment, exhibited the greatest release of pH content, reaching a percentage of 6.87% statistically alike with the T_1 treatment (6.67) under anaerobic conditions. The, rest of the treatments released statistically alike quantity of PH. However, the T_2 treatments released the lowest amount of pH (6.53) under anaerobic conditions. On the 75th day, all the treatments released statistically alike amount of PH (6.60). There was no significant variation among them (Table 4.3). On the 90th day, all the treatments released statistically alike amount of pH except T_4 and T_6 where they released lowest amount of pH. However, the maximum pH released from T_2 (6.60) followed by T_1 (6.57) and minimum from control (6.20) under anaerobic conditions (Table 4.3).

The pH concentration varies in decomposing materials like mustard oil cake, fish meal, bone meal, biochar-enriched organic fertilizer, and vermicompost due to the diverse biochemical processes involved in their decomposition. Different materials contain varying levels of organic compounds, proteins, fats, and minerals, which break down at different rates and produce different by-products. The microbial activity during decomposition also influences pH, as various microbes prefer different pH levels and produce acids or bases as metabolic by-products. Additionally, the presence of buffering agents in materials such as biochar can stabilize pH, whereas the lack of such agents can lead to more significant fluctuations. Lastly, the initial pH of the materials and the environmental conditions, such as moisture and temperature, also play crucial roles in determining the final pH during decomposition. Some soil characteristics, such as type, depth, temperature, moisture content, pH, C/N ratio and complex carbohydrate content influence the mineralization of organic manures in soil (Sleutel *et al.*, 2009).

Table 4.3 Effect of different treatments on pH release content of the soil sample

Treatment	1 Day	15 Day	30 Day	45 Day	60 Day	75 Day
T_1	6.63 ab	6.60 a	6.83 a	6.57 ab	6.67 ab	6.60 a
T_2	6.70 ab	6.67 a	6.27 c	6.77 a	6.53 b	6.60 a
T_3	6.57 b	6.53 ab	6.57 b	6.57 ab	6.57 b	6.57 a
T_4	6.67 ab	6.33 b	6.63 b	6.43 ab	6.57 b	6.60 a
T_5	6.73 a	6.37 b	6.53 b	6.47 ab	6.60 b	6.60 a
T_6	6.73 a	6.50 ab	6.60 b	6.37 b	6.87 a	6.70 a
LSD	0.15	0.20	0.12	0.34	0.22	0.21
Level of Significance	NS	*	**	NS	*	NS

Here, mean with similar letter do not differ significantly

Here, T_1= Mustard oil Cake, T_2= Fish meal, T_3= Bone meal, T_4= Biochar enriches organic fertilizer, T_5= Vermicompost and T_6= control

4.4 Effect of different treatments on EC release content of the soil sample

The release of EC content showed significant variation on different date among the samples due to different treatments. All the treatments recorded the statistically alike release of EC content on Day 1. The T_1 treatment gave the highest release of EC (0.18%) followed by T_2 (0.17%) and T_3 (0.16%) under anaerobic conditions. However, the T_6 (control) treatments recorded the lowest release of EC content (0.13%) under anaerobic conditions. On Day 15, the T_1 treatment and the T_2 treatment had the highest release of EC levels (0.66 and 0.49 respectively) under anaerobic conditions. All the rest treatments exhibited the statistically lowest release of EC value. However, the control treatment recorded the lowest EC released value (0.11%). On Day 30, the T_1 treatment had the highest EC release (0.70) which is statistically different from others. The T_2 treatment released the intermediate amount of EC (0.39%) under anaerobic conditions. The rest of the treatments showed the statistically alike release of EC where T_6 released the lowest amount of EC (0.10%) under anaerobic conditions. On the 45th day, the T_1 treatment released the highest levels of EC (0.67%) which is statistically similar to T_2 treatment. However, the T_6 (control) treatments showed the lowest EC release (0.11%), which is statistically similar to all the treatments except T_1 and T_2 under anaerobic conditions. On the 60th day, the T_1 treatment, exhibited the greatest release of EC content (0.50%) statistically unlike with other treatment. Followed by it T_2 gave the second highest release of EC (0.31). However, the T_6 treatments released the lowest amount of EC (0.11) statistically alike to rest of others. On the 75th day, the T_1 treatment, exhibited the greatest release of EC content (0.37%) statistically unique with other treatment. Followed by it T_2 gave the second highest release of EC (0.22) under anaerobic conditions. However, the T_6 treatments released the lowest amount of EC (0.11). On the 90th day, the T_1 treatment, exhibited the greatest release of EC content, (0.35) statistically alike with T_2 and T_3 treatment (0.32 and 0.28 respectively). However, the T_6, T_4 and T_5 treatments released the lowest amount of EC (0.13, 0.17 and 0.17, respectively) under anaerobic conditions (Table 4.4).

Mustard oil cake is likely to release the highest EC (Electrical Conductivity) under anaerobic conditions compared to bone meal, fish meal, biochar, and vermicompost due to its readily decomposable organic matter content. Mustard oil cake is rich in soluble nutrients and proteins, which break down quickly in the absence of oxygen, releasing electrolytes that contribute to a higher EC. In contrast, bone meal and fish meal have a slower decomposition rate due to complex organic structures. Biochar, while high in carbon, holds onto nutrients tightly, and vermicompost, though nutrient-rich, releases them more gradually (Bera *et al.*, 2014).

Table 4.4 Effect of different treatments on EC release content of the soil sample

Treatment	1 Day	15 Day	30 Day	45 Day	60 Day	75 Day
T_1	0.18 a	0.66 a	0.70 a	0.67 a	0.50 a	0.37 a
T_2	0.17 a	0.49 ab	0.39 b	0.51 a	0.31 b	0.22 b
T_3	0.16 a	0.15 b	0.13 c	0.14 b	0.17 c	0.16 bc
T_4	0.15 a	0.12 b	0.12 c	0.14 b	0.14 c	0.13 c
T_5	0.15 a	0.12 b	0.12 c	0.11 b	0.11 c	0.12 c
T_6	0.13 a	0.11 b	0.10 c	0.11 b	0.11 c	0.11 c
LSD	0.06	0.39	0.04	0.26	0.07	0.08
Level of Significance	NS	*	**	**	**	**

Here, mean with similar letter do not differ significantly

Here, T_1= Mustard oil Cake, T_2= Fish meal, T_3= Bone meal, T_4= Biochar enriches organic fertilizer, T_5= Vermicompost and T_6= control

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the department of Soil Science, HSTU, Dinajpur during November 2016 to April 2017 to studies on the mineralization of N and S in concentrated organic manures in anaerobic condition under laboratory incubation. The soils samples used for this study were collected at a depth of 0–15 cm from the Field Laboratory of Soil Science Department, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200. The soil sampling site lies between located in between 25°10' and 26°04' north latitudes and in between 88°23' and 89°18' east longitude, and the experimental soil was characterized as Non-Calcareous Grey of Piedmont plain and Tista Floodplain soil under the agro-ecological region of the AEZ (Old Himalayan Piedmont Plain) (FAO, 1988 and UNDP, 1988). In this experiment, T_1= Mustard oil Cake, T_2= Fish meal, T_3= Bone meal, T_4= Biochar enriches organic fertilizer, T_5= Vermicompost and T_6= control was used as treatments. The physicochemical properties of the available P and available S, pH and EC was assessed by standard protocol.

The result of the experiment shows that the maximum available S 26.76, 32.77, 42.18, 24.89, 91.99,102.9 and 84.76% were recorded from T_1 (mustard oil cake) treatment at day 01, 15, 30,45, 60, 75 and 90 respectively. In most of the cases, T_2 (fish meal) gave the statistically alike result of the highest result. The control treatment gave the lowest value for available S.

For available P the T_1 (mustard oil cake) showed the maximum value at day 01, 15, 30, 45, 60, 75 and 90 days (4.99, 5.50, 5.63, 6.65, 6.51, 14.12 and 20.24% respectively). In some cases, fish meal also recorded the topmost value for available P. The control treatment gave the lowest value for available Phosphorus.

The T_1 treatment and T_5 treatment recorded the highest release of pH content (6.73%) on Day 1. On Day 15, the T_2 treatment and the T_1 treatment had the highest release of pH levels (6.67% and 6.60%, respectively). On Day 30, the T_1 treatment had the highest pH release (6.83%) which is statistically different from others. On the 45th day, the T_2 treatment using fish meal released the highest levels of pH (6.77%). On the 60th day, the T_6 treatment, exhibited the greatest release of pH content (6.87%) statistically alike with the T_1 treatment (6.67). On the 75th day, all the treatments released statistically alike amount of pH (6.60). On the 90th day, all the treatments released statistically alike amount of pH except T_4 and T_6 where they released lowest amount of P^H.

The T_1 treatment recorded the highest release of EC content (0.18%) on Day 1. On Day 15, the T_1 treatment gave the highest release of EC content (0.66%). On Day 30, the T_1 treatment had the highest EC release (0.70) which is statistically different from others. On the 45th day, the T_1 treatment released the highest levels of EC (0.67%). On the 60th day, the T_1 treatment, exhibited the greatest release of EC content (0.50%). On the 75th day, the T_1 treatment, exhibited the greatest release of EC content (0.37%). On the 90th day, the T_1 treatment, exhibited the utmost release of EC content (0.35%).

Composition of manures, local management techniques in terms of treatment, storage and field application and ambient climatic conditions have a significant impact on nutrient mineralization. To maintain soil fertility, the most appropriate source of organic amendment should be chosen based on the farm's needs. The nutrient release pattern should be developed first considering the soil condition, and then there must be adequate coordination of nutrient input and crop demand based on the data obtained from farm manure mineralization research. The use of manure at the right time and in the right amount will prevent nutrient shortage or over usage in crop production, provide balanced fertilization and, ultimately, save our ecosystem.

However, further research should be done in different environment with different treatment combinations to get more accurate result.

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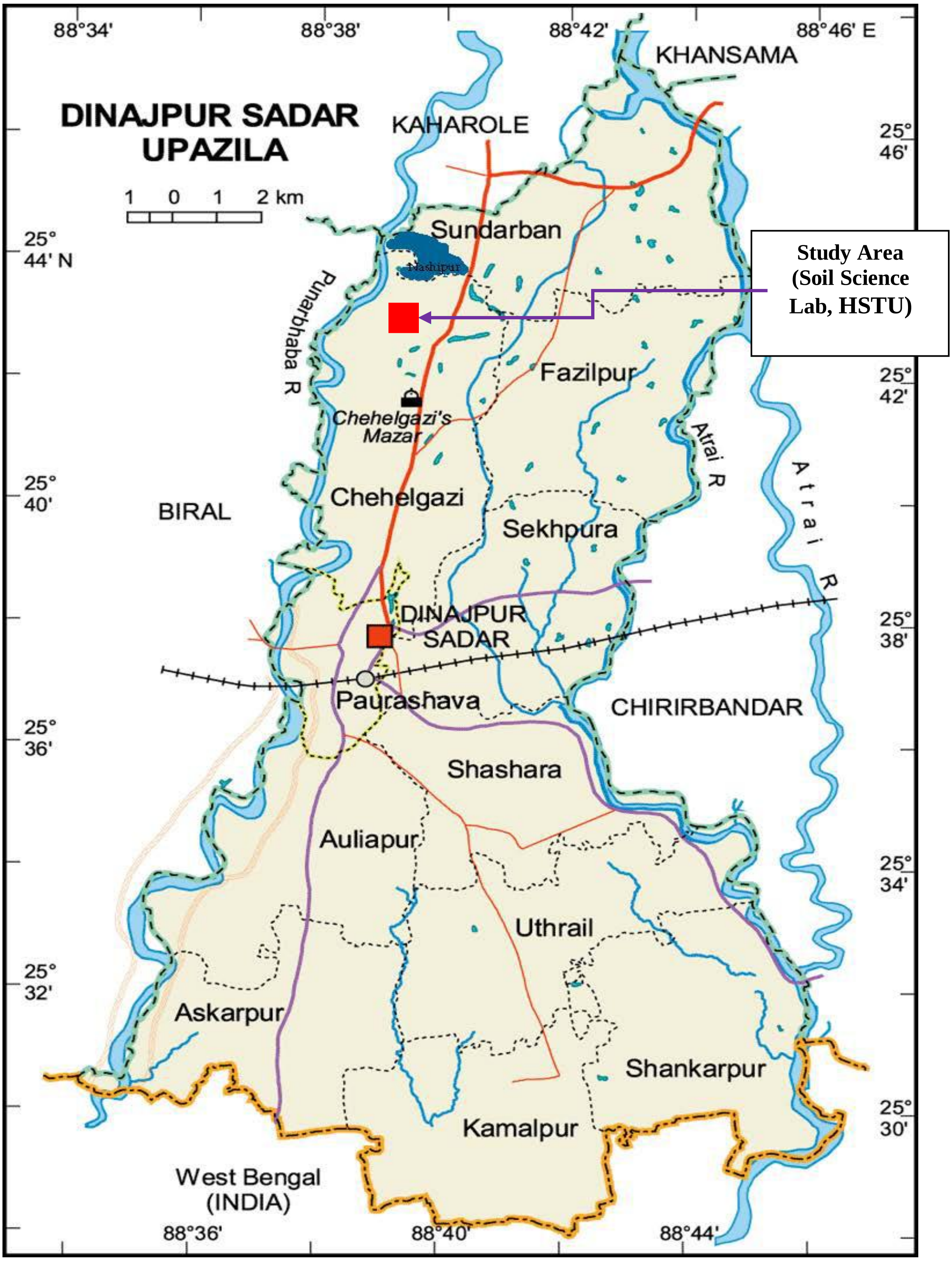
APPENDICES

Appendix I. Location of the experimental site (map of Dinajpur Sadar Upazila showing the research area)



Appendix II. Experimental photo