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Assessment of Biodegradation and Trace Element Content of Three Animal Wastes

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ABSTRACT

Biodegradation and trace element content of three different animal wastes were evaluated in green house study. The study was a factorial experiment in a randomized complete block design (RCBD) with three different rates of 0, 5, 10 and 20 tha^{-1} each for poultry manure, pig manure and cow dung. Each treatment was replicated three times. The result showed that biodegradation rate of the wastes varied while poultry manure (PM) and pig manure (PG) decomposed fast, cow dung (CD) decomposed relatively slow. Hence nutrient release ability will be more on the PM and PG than in CD. The result of the study showed that it will require more oxygen to degrade CD than PG or PM thus cow dung has higher pollution potential followed by PG and PM. The result also showed that the incorporation of the animal wastes enriched maize shoot with trace metals. These metals at above critical levels are toxic to animals and human beings.

Introduction

The south eastern soils of Nigeria are low in organic matter content and very deficient in N available P and exchangeable bases due to high rainfall and temperature. This result to low productivity of the soils that is well experienced in the area. Even the efficiency of the uptake of mineral fertilizer is very much influenced by organic matter content of the soil. Thus the deterioration of soil whether physical, biological or chemical can be associated with the depletion of soil organic matter content. Unless the soil organic matter content is adequately improved, sustainability of crop production will be at stake or impossible. The addition of organic matter to the soil not only prevent contamination of food by chemicals but also to make degraded and marginal soil healthy and productive. The use of organic waste manure is not only for better utilization of applied fertilizer but also to make the soil productive and agriculturally sustainable. This has led to increased studies on organic wastes as a means of improving the organic matter content of the soil.

The use of animal wastes as a bio-fertilizer has provoked many studies aimed at evaluating the fertilizing value of these products. The agricultural value of animal wastes centred on their composition and ability to release into the soil the nutrient elements required for the growth of the plant. Animal wastes are subject to microbial decomposition and tend to release the nutrients therein rapidly into the soil. The use of animal wastes to improve the organic matter content and productivity of the soil have been well documented (Nweke, 2019). Animal wastes provide a substrate for continuous decomposition by microbial organism and consequent gradual input of soil organic matter, thereby improving soil physically, biologically and chemically. The agronomic and soil nutrient benefit derived from animal waste application not withstanding harmful effect may result from their application especially at high dose or repeated applied dosage, Such increase in the amount of certain essential micro nutrient to toxic level can increase the uptake of other heavy metals entering food chain affecting plant, animal and human beings. Thus the essence of this study is to evaluate the biodegradation rate and trace element potentials of three rates of three contrasting animal wastes.

Materials and Methods

0-20cm top soil of an ultisol belonging to Nkpologwu series and located on the University of Nigeria Nsukka, Teaching and Research Farm was collected using soil auger. The soil sample was air dried at room temperature about 26^{o}C and sieved through a 2mm sieve. The animal wastes (Cow dung, Pig manure and Poultry manure) were collected from the cow, piggery and poultry sections of the Department of Animal Science farm of the University of Nigeria Nsukka. Each waste material was dried at room temperature and crushed to fine particles (< 2mm). Maize (Western yellow var. NSI) used as a test crop for the study was purchased locally. The study was carried out in the department of Soil Science green house complex of the University. Before planting maize 4kg of soil was weighed out and mixed thoroughly and separately with the following rates of cow dung, poultry manure and pig manure 0, 0.25, 0.50 and 1.00% an equivalent of 0, 5, 10 and 20tha^{-1}. They were transferred in to clay pots with drainage holes at the base. To avoid excessively loss of water by drainage the holes were plugged with cotton wool. The soil and the amendment mixtures were incubated for one week before planting maize. This was to give time for transformation and possible detoxification of harmful materials that might be produced during the decomposition of the wastes.

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Five seeds of maize NS1 variety were planted per pot and later thinned down to three stand per pot after germination. The experiment lasted for 42 days of growth, the shoots were careful harvested, cut and oven dried at 60% for seven days and use for trace element determination.

Laboratory analysis

Before and at end of the study the following chemical properties were determined

Physical properties: Particle size distribution was determined by hydrometer method (Bouyoucos 1951).

pH determination

For the soil and soil/amendment mixtures pH was determined in duplicates both in distilled water and in 0.1N KCl solution using soil/liquid ratio of 1:2.5. After stirring for 30 minutes the pH values were read by using a Beckman and Zeromatic pH meter (Peech 1965).

Organic carbon

This was determined by the Walkley and Black (1934) method as modified by Allison (1965). The percentage organic matter was calculated by multiplying the figure for organic carbon by the conventional Van Bemmeler factor of 1.724 which is based on the assumption that soil organic matter contains 58% C (Allison 1965)

Total Nitrogen

Total nitrogen was determined by Kjeldahl method (Bremner, 1965) using $CuSO_4/Na_2SO_4$ catalyst mixture. The ammonia (NH_3) from digestion was distilled with 45% NaOH into 2.5% Boric acid and determined by titrating with 0.05 NHCl.

Exchangeable basis

The complexiometric titration method describe by Chapman (1965) was used for the determination of calcium and magnesium. Sodium and potassium were determined from IN ammonium acetate (NH_4OAC) using the flame photometer.

Available phosphorous

This was determined by Bray II method (Bray and Kurtz, 1945). The available P was read off from the standard curve after obtaining the optical density from a colorimeter.

Cation exchange capacity

The apparent cation exchange capacity of the soil was obtained by the ammonium acetate (NH_4OAC) method (Jackson, 1958).

Amendment decomposition study (CO_2 evolution)

This was carried out using titrimetric determination of carbon dioxide (CO_2) evolution by the Blom and Edelphavsen (1955) method. The incubation lasted for 16 weeks

After the harvest, soil samples were collected from pots amended with 20tha^{-1} animal waste and air dried, followed by careful removal of the plant root. The residual organic carbon content was then determined and used to calculate the mineralization rates constant, using the equation

$K= [2.303/ (t_2-t_1)] \log C_1/C_2$ proposed by Gilmour et al. (1977)

Where K is the organic carbon mineralization rate constant (g/day), C_1 is the amount (g) of organic carbon in the soil at the beginning of the experiment (t_1) and C_2 is the residual amount (g) of organic carbon at end of the study (t_2), with t_2-t_1 expressed in days. The half-life of the material was determined by $T_{50} = \ln \frac{(0.50)}{K} = \frac{0.693}{K}$

Where T_{50} is the half-life that is the time it took 50% of the wastes to mineralize.

Trace metal determination

Maize plants harvested from pots amended with 20tha^{-1} were used for trace metals determination. The trace metals Fe, Cu, Zn, B, and Pb were determined using atomic absorptiometry after digestion with conc HNO_3 while B was determined by hot water extraction method.

Biological and chemical oxygen demand

The biological and chemical oxygen demand of the wastes were determined in the sanitary Engineering Laboratory of the Civil Engineering, Department University of Nigeria Nsukka. The procedures are those used in standard methods for examination of water and waste water.

Data analysis

Collected data were analysed according to the procedures for a factorial experiment in a randomized complete block design by Little and Hills (1978) Duncan's multiple range test was used to detect differences between treatment means

Results and Discussion

The result of the physicochemical properties of the soil before the commencement of the study presented in Table 1 showed the soil to be acidic and low in chemical nutrients, while their concentration in the animal wastes were found to be high. Thus indicating that the soil and maize plant will benefit from their application.

Table 1. Properties of soil and Animal wastes before the commencement of the experiment

Parameters	Soil	CD	PM	PG
Silt%	2	-	-	-
Clay %	12	-	-	-
Fine sand%	36	-	-	-
Coarse sand%	60	-	-	-
Textural class	Sandy	-	-	-
OC %	0.56	7.86	13.50	6.84
OM%	0.96	13.55	23.29	11.79
TN%	0.067	1.85	2.86	2.00
Na meq/100g soil	0.11	0.43	0.72	0.44
K meq/100g soil	0.15	0.48	1.50	0.65
Ca meq/100g soil	0.8	1.50	8.10	2.30
Mg meq/100g soil	0.6	1.29	6.89	1.09
Avail. P ppm	3.2	0.23	2.05	0.82
CEC meq/100g soil	7.0	-	-	-
pH H_2O	4.80	6.69	7.11	6.38

Biological and chemical oxygen demand

The result presented in Table 2 showed the values of biological oxygen demand (BOD) and chemical oxygen demand (COD) of three different animal wastes studied. Cow dung, poultry and pig manure. The BOD of the three animal wastes showed a result variation of PG > CD > PM. The BOD of organic wastes like animal wastes is measured in parts per million (PPM) or milligrams per litre (Mg/L) of the oxygen (O_2) required by microorganisms either present in the waste or added to decompose organic waste in to simple compounds such as glucose and lactose. The process being a limited speed reaction is thus defined BOD over 3-5 days (BOD5 or BOD3). The fifth (5) day limit tend to restrict the BOD to that required for the breakdown of organic carbon (OC) while organic nitrogen (ON) evolve as ammonical nitrogen which is broken down after the 5 days. In a well aerated soil all the OM found are subject to oxidation. For organic N the process is believed to follow this part of reactions;

$$\text{Organic matter} \xrightarrow[\text{Oxidation}]{\text{Microbial}} NH_2 + CO_2 + H_2CO_3 + \text{Energy} + \text{other products}$$

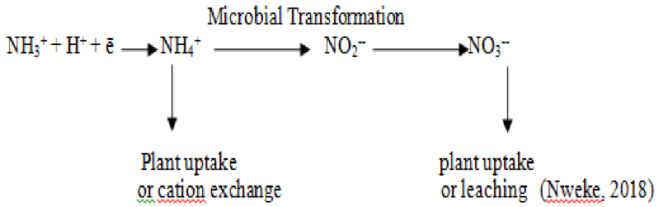
Amines and Amino-acid

The energy released at this stage and some of the nitrogen are further utilized by the microorganisms in the decomposition of amine and amino acid leading to ammonification

$$R\text{-}NH_2 + H_2O \xrightarrow[\text{Oxidation}]{\text{Microbial}} R\text{-}OH + NH_3 + H_2CO_3 + \text{Energy} + \text{other products}$$

Ammonia

The ammonia formed is then converted by oxidation - reduction reaction to the forms NH4 + N and NO_3 – N respectively which are available and useable by plants. The first step of the reaction is that Ammonia is converted to Ammonium ($NH4^+$) and then nitrate (NO_3^-) by the following reaction;



The BOD test is principally used to assess the strength in terms of oxygen need to stabilize the decomposition process of organic waste by microorganism. However the higher the BOD the more the pollution (harmful) potential of the waste material. Thus the pollution potential rank of the 3 animal wastes will be PG > CD > PM. Indicating that higher pollutant is there in PG compared to that of CD and PM. Chemical oxygen demand (COD), the result indicated CD to have recorded the highest value of COD next in rank being PM and the least PG. The COD is the amount of O_2 required for the total degradation of all organic compounds in organic wastes into simple material such as CO_2, N_2O, NO_3, H_2O, SO_4, etc. When the result values of BOD and COD are conjunctively considered the ranking of the animal wastes showed CD > PG > PM, the implication of the result scenario is that it will require more amount of oxygen to decompose CD than PG or PM. Thus making CD the highest pollution potential followed by PG and last PM. Thus through this kind of study (BOD & COD), the toxic strength and resistant substance of animal wastes, agricultural wastes or industrial wastes can be assessed or evaluated. When BOD/ COD ratio is considered it tend to show how easy or hard organic waste materials can be decomposed by bacteria. Hence higher ratio indicate easily degradable but as the ratio draws near to zero the organic matter becomes less easily degradable.

Table 2. Biological and chemical oxygen demand of animal wastes

Animal wastes	BOD^5 mg/l	COD mg/l	Ratio
CD	48	299	1:6
PM	40	120	1:3
PG	58	77	1:1

CO_2 evolution following decomposition of animal wastes

The result in Table 3 showed the decomposition studies of the 3 animal wastes studied. Decomposition increased in early period of incubation and then decreased progressively though not in all treatment. A decline in decomposition process following weeks of incubation was observed in all the treatment till the 9th week for CD, PM and PG except for CO that showed rise in 3rd week. A rise was however observed in the 10th week of which the decomposition process declined continuously in PG till the 16th week of the incubation. There was stabilization in 13th and 14th week of the incubation with regard to PM degradation but continued decline afterwards while CD and CO show stabilization phase in decomposition in 14–16th week of incubation. The stabilization phase in the decomposition rate perhaps may suggest that the activities of microorganisms involved in the decomposition are in equilibrium with the resources such that no change could be expected or that carbon content has being totally used up by

Table 3. CO_2 evolution (mg) following decomposition of animal waste

Treatment	Weeks of decomposition															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CO	56.1	26.4	20.9	17.1	28.1	15.0	15.4	15.4	14.3	10.5	13.0	13.2	5.5	4.4	4.4	4.4
CD	96.8	71.5	62.7	48.4	40.7	40.7	28.6	31.9	29.7	30.8	20.9	14.3	26.4	8.8	8.8	8.8
PM	113.1	79.2	79.2	44.0	35.2	23.5	20.9	18.7	16.5	17.6	15.4	12.1	28.6	28.6	13.2	12.1
PG	111.1	82.5	59.4	39.6	40.7	31.9	31.9	28.6	28.6	33.0	19.8	15.4	17.6	16.5	13.2	12.1

Table 4. Cumulative CO_2 evolution (mg)

Treatment	Weeks of decomposition															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CO	56.1	82.5	103.4	121.0	144.1	160.6	176	191.4	205.7	222.2	235.2	248.4	253.9	258.3	262.7	267.1
PG	111.1	193.6	253	202.6	333.3	365.2	397.1	425.7	454.3	487.3	507.1	522.5	540.1	556.6	569.8	581.9
CD	96.8	168.3	231	279.4	320.1	360.8	389.4	421.3	451	481.8	502.7	517	543.4	552.2	561	569.8
PM	113.3	192.5	254.1	298.1	333.3	358.6	379.5	398.2	414.7	432.7	447.7	459.8	488.4	500.5	513.7	525.8

Table 5. Decomposition rate constant and half-life of the treatments

Treatment	Mineralization rate constant (K)	Half-life (T_{50})
PM	0.027785	25
PG	0.018837	37
CD	0.015532	45
Mean	0.020751	36

Table 6. Effect of animal wastes on trace element (PPM) content of maize shoot

Treatment	1st Year					2nd year				
	Fe	Cu	B	Pb	Zn	Fe	Cu	B	Pb	Zn
CD20	25	7.24	35.8	62.4	19.56	24.75	6.19	34.85	61.56	19.32
PM20	25	7.24	37.8	66.4	19.56	23.89	6.48	35.75	65.85	19.30
PG20	25	7.24	37.8	60.4	32.60	23.98	6.59	36.29	59.96	31.59
CO	20	10.86	35.2	48.2	13.04	19.97	9.87	34.35	47.68	12.98
LSD0.05	0.33	0.44	0.19	0.34	0.58	0.29	NS	NS	0.36	0.69

the degrading microbes. When the result in Table 3 are viewed critically it showed that it had two distinct parts, the first part is of higher values indicating rapid and vigorous decomposition followed by the second part of lower values suggesting low rate of decomposition.

The Table 4 result merely showed the cumulative values of CO_2 evolution from the decomposition studies. Generally, the result indicated that the decomposition rate of the wastes followed the order PM > PG > CD. Increase in the waste degradation at the initial period of the incubation may suggest high carbon content that energized the activities of the bacteria for rapid degradation. The cumulative result in Table 4 showed the PM to have decomposed rapidly compared to PG and CD probably because of its high nitrogen and organic matter content (Table 1) that enhance higher microbial population. In this case it can be considered of high quality compared to the other treatments.

Decomposition rate constant and half-life of the wastes

The result in Table 5 showed the decomposition rate constant and half-life of the wastes used for this study. The result indicated that decomposition rate constant (K) of the wastes (g/day) varied among the treatments. The half-life (T_{50}) showed that it took 25days for 50% of poultry manure (PM) to decompose and release its nutrients into the soil as against 37 days of pig manure and 45 days of cow dung. Thus indicating that mineralization rate was higher in order of PM > PG > CD. The higher decomposition and mineralization rate observed in PM compared to PG and CD probably may be associated to its fine waste texture that creates enough surface area for easy and fast attack by soil microbes leading to fast release of plant nutrients in to the soil. This resulted in the enrichment of the soil with plant nutrients and higher maize yield recorded by Nweke and Igwe (2020) in agronomic aspect of this study. The CD following its half-life result tend to be resistant to microbial attack probable due to its ‘rough’ texture relative to PM and PG and therefore releases its plant nutrients rather slowly. This corroborates with the observations of Parr et al. (1987) that organic wastes with rapid decomposition by soil microorganism release their nutrients fast while those that are resistant to microbial attack release their nutrients slowly. In contrast residual improvement in the structural composition and reclamation of the degraded and marginal soils can be achieved in a long term with resistant organic materials like cow dung (CD) due to its organic stability.

Uptake of trace elements by maize shoot

The total concentration of Cu, Fe, B, Pb and Zn taken up by maize shoot after each year study are shown in Table 6. The result of these parameters showed significant ($P < 0.05$) different among the treatment in first year and decreased progressively and significantly except for the result of Cu and B in the 2nd year planting result. The value recorded for Fe in first year planting indicated statistically similar result for CD, PM and PG but significantly higher than CO value. The result scenario also applied to CU except that CO valve is higher than the value obtained for CD, PM and PG. The PM and PG show similar result of 37.8ppm for B while CD and CO values were almost similar since the difference in their value is merely 0.6ppm. The lead (Pb) content of the shoots in the 1st year planting showed an order of PM>CD>PG>CO. Zn showed a higher content in PG relative to the other treatments, while similar values were observed in CD and PM. The second year planting showed decreased value in all the parameters relative to their 1st year planting values. Fe and Cu showed a result order of CD > PG > PM > CO and CO > PG > PM > CD respectively in the 2nd year planting. The result of B, Zn and Pb indicated higher values in PG, (B and Zn) and PM (Pb) respectively relative to the other treatment studied. The higher content of the trace metals observed in the maize shoot could be attributed to the organic matter, CEC and clay content in the soil and treatment studied (Table 1). Organic matter have high affinity for trace metals and its addition to soil removes the metals from the soil solution probably through chelation processes and fixation thereby preventing their removal or leaching from ground waters. Maize roots pick up these metals as mobile ion (Fe^{2+}, Cu^{2+}, B^{4+}, Pb^{4+}, Zn^{2+}) from the soil solution. The uptake of these mobile ions by maize plant will lead to bio accumulation of the elements in their tissue leading to health complications in both animal and man. Kumar and Babel (2011) and Kabata- Pendias and pendias, (2011) noted that clay and CEC significantly influenced availability of Cu as they contribute to increasing the exchange sites on soil colloids. The work of Nweke et al. (2017) equally indicated that organic waste application on soil can give rise to excessive absorption of the heavy metals in seeds and shoot of plants and their content in soil. The lower content of Fe, Pb and Zn observed in CO relative to the amended soil perhaps may be attributed to immobilization resulting to their lower level in maize shoot. The implication of higher values recorded for these heavy metals is that organic waste applied at higher rate like the one studied, is capable of increasing the health challenges of man as their journey begins in man's body through plant consumption where they are readily absorbed. The presence of lead (Pb) in food for example causes severe brain damage and intellectual impairment. Hence care should be taken in the use of organic waste as soil bio fertilizer, rates of application visa - vie their environmental pollution through their trace metals content.

Conclusion

The findings from this study have shown that the BOD, COD decomposition rate and trace metal content of maize shoot of the animal waste varied. Poultry manure decomposed faster and release its nutrient quickly while pig manure and cow dung decomposed relatively slowly. Meaning that nutrient release and availability to plant will be more with PM amendment. Decomposition rate study equally showed that 7 days are required before planting on soil amended with animal wastes. The animal waste studied also show potential pollutants and when added to the soils in high rate creates or produce undesirable effect due to an increase in the amount of toxic metals in the maize shoot. These metals when they enter the food chain or web adversely affect animal and man alike. The cumulative pollution potential ranking showed CD > PG > PM. This studies can be concluded by saying that animal waste decomposes with appropriate incubation period and release their nutrient to soil environment that will increase the growth and yield of test crops. That they are potential pollutants especially at higher rates.

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