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Mineralization of Nitrogen in Hydromorphic Soils Amended with Organic Wastes

[1]IWEGBUE C.M.A AND; [2]EMUH, F N; [1]BAZUNNU, A O; [3]EGUAVOEN O

[1]*Department of Chemistry, Delta State University, Abraka P.M.B. 1 Abraka, Nigeria*
[2]*Department of Crop/Soil Science, Delta State University, Anwai-Asaba Campus, Asaba, Nigeria*
[3]*Ambrose Alli University, P.M.B 14 Ekpoma, Edo State*

ABSTRACT: This paper present the results of nitrogen mineralization in hydromorphic (wetland) soils of the Niger Delta amended with organic wastes. The organic wastes amended soil generally showed a decrease in total inorganic (NO_3-N+NH_3-N) released within first 14 days, which increased thereafter. The nitrogen mineralized during 58 day of incubation ranged from 82.15 mg kg^{-1} to 281.60 mg kg^{-1} for fadamal soil, 54.50 mg kg^{-1} to 197.30 mg kg^{-1} for meander belt soil and 98.50 mg kg^{-1} to 320.00 mg kg^{-1} for Mangrove soil (mangal acid sulphate soils). The order of cumulative nitrogen released in the waste amended soil followed the order: sewage sludge>kitchen waste> poultry manure> oil palm waste> cow manure. Total mineralized N indicated negative correlation with total organic N and C: N ratio. @JASEM

Keywords: N-immobilization; Mineralization; Wetland soils; Niger Delta; Nigeria.

The concept of recycling waste nutrients and organic matter implies that agricultural land is feasible and desirable. Land application represents an economically desirable outlet for the producer of waste and a potential cheap source of organic matter and fertilizer elements for landowners. More so, because of the increasing energy requirement for production of synthetic fertilizers, the cost and environmental problems associated with alternative disposal methods. Of the many problems associated with organic farming and various soil management practices, including minimum and no-till system, nutrient cycling in organic waste-treated soils deserved attention. Information on the relative degree of nutrient release (mineralization) and nutrient tied-up (immobilization) in soil treated with various organic waste materials are therefore needed.

The fate of nitrogen in waste amended soil has been documented (Chae and Tabatabai, 1986; Pettygrove *et al*, 2003; Rubuduka *et al*, 1993; Murwira and Kitchman, 1993, Kachaka *et al*, 1993; Iwegbue e*t al*., 2006). Pettygrove *et al*. (2003) reported that net mineralization in a sandy loam soil (pH7.6) amended with dairy manure water and dairy manure shows that the net mineralization of Nitrogen for dairy manure was rapid during the first 21 days and was slow and variable thereafter. The two manures showed initial net mineralization, then immobilization. For the eight other manures, apparent net mineralization during the first 21 days averaged 15-20% of the manure organic N. The liquid density, total suspended solid and organic nitrogen were found to be related to the 21 days net mineralization. Chae and Tabatabai (1986) reported that mineralization of nitrogen in soil amended with different waste materials exhibited a slow initial rate, which was indicative of the lag period, followed by rapid increase in rate and subsequent slow N release. The total nitrogen mineralized from the organic waste materials varied considerably depending on the soil type and organic material.

The kinetics of nitrogen mineralization in organic wastes amended soil have been described with first order reaction kinetics (Chae and Tabatabai, 1986; Cheschair *et al.,* 1986; Murwira and Kirchman, 1993; Christensen and Olesen, 1988) or a set of first order kinetics (Gale and Gilmour, 1986). This communication present the results of mineralization of nitrogen in typical wetland soils of the Niger Delta amended with organic wastes with a view of providing information on crop nitrogen requirement.

MATERIALS AND METHODS

Three surface soils of 0-15cm (Table 1) selected to represent some major soil series in the Niger Delta and include a wide range of chemical and physical properties. The samples were collected at latitude 5^0 45^1N and longitude 6^0 7^1 E ,latitude 5^0 15^1 N and longitude 6^0 11^1 E and latitude 5^0 36^1 N and 5^0 46^1 E for fadamal soil, meander belt soil and mangal acid sulphate soil respectively Samples of field moist capacity were brought to the laboratory, pass through a 2mm screen and divided into 2 portions. One was placed in a polyethylene bag and stored at 4^0C, and a sub sample of this portion was used in the incubation experiment to study mineralization.

The second portion of soil was air dried at room temperature for 48 h and stored in a tightly sealed bottle. A sub sample of the air-dried portion was used for the determination of chemical properties.
Sewage sludge was collected from the Shell Petroleum Development Company (SPDC) sewage treatment plant at Edjeba, Warri. To speed up the air-

*Correspondence author: maxipriestley @yahoo.com

drying the sludge was spread on plastic tray 30 x 50 cm placed in well-ventilated hood. A fan was directed towards the hood to enhance evaporation of the liquid. By this procedure, the sludge was normally air-dried with 24 – 48 h. Thereafter, the material was weighed and was ground to pass 2 mm sieve.

The kitchen waste, poultry waste, cow manure was collected fresh and dried in a manner similar to that described for sewage sludge samples. After air-drying; they were ground to pass 2 mm mesh sieve 850 (µm). The sewage sludge and other organic wastes were stored at 4^{o}C.

In the analysis reported in Table I and II, pH was determined by a glass electrode (soil/water ratio 1:2.5) sewage sludge before drying and animal manures at waste/water ratio 1:10) (McLean, 1982). Total organic carbon was determined by wet dichromate method of Walkley and Black (Nelson and Sommer, 1982). Total nitrogen was determined by using the semi-macro Kjeldahl method (Bremner and Mulvaney, 1982). Mineral nitrogen was determined by colorimetric method (Keeney and Nelson, 1982) after extraction with 2M KCl. The particle size distribution was by hydrometer method for silt and clay, and by dry sieving for sand fraction (Reeuwijk, 1995).

The incubation experiment was done in the laboratory of field capacity and at constant temperature of 25^{0}C. Soil samples (each 100 g) were thoroughly mixed with 200 mg dry weight (equivalent to 40 tones per hectare) of the waste and placed 100 ml incubation vessel. Samples for total organic and inorganic nitrogen were taken at day 0, 14, 28, 42 and 58 days. The total inorganic nitrogen mineralized during incubation was determined after extraction with 2 M KCl by the procedure previously described.

RESULTS AND DISCUSSION

The five organic wastes displayed a wide range of net mineralization value in the different soil types (Figures 1, 2 and 3). The organic waste amended soils generally showed a decrease in total amount of inorganic nitrogen (NO_3-N+NH_3-N) released after 14 days and thereafter increase in total amount of inorganic released. This agrees with observations of Haque and Walmsley (1972) who opined that the immobilization of N during the initial period of incubation, followed by mineralization of N in the later period. Analysis of variance(ANOVA) at $p<0.05$,show that the pattern and amount of nitrogen mineralized from the organic wastes studied varied, depending on the waste type and soil to which the material was added. All the waste types showed significant higher amount of nitrogen mineralized compared to the controls. Table 1 and 2 reports some physicochemical properties of the soil and waste types used for the incubation. The results revealed apparent and significant variability in the physicochemical properties of the waste and soil types used for the incubation experiment.

Table 1. Some properties of soil used

	pH	Total N (%)	NH_3-N (mgkg^{-1})	NO_3-N (mgkg^{-1})	Total Min-N (mgkg^{-1})	TOC (%)	Ash (%)	Texture	C:N
Soil									
Famadal soil	7.16	0.06	5.25	9.76	15	1.73	92.07	Sandy	28.83
Meander belt soil	6.31	0.13	4.68	10.92	10.92	5.24	90.96	Sandy clay loam	40.31
Mangrove soil (mangal-acid sulphate)	6.61	0.50	40.00	60.00	100.0	12.76	78.03	Sand clay loam	25.48

Table 2: Some properties of the organic wastes used

Wastes	pH	Total N (%)	NH_3-N (mgkg^{-1})	NO_3-N (mgkg^{-1})	Total Min-N (mgkg^{-1})	TOC (%)	Ash (%)	C:N
Cow dung	12.59	1.70	265.2	244.8	510	49.17	15.23	28.92
Poultry manure	9.54	2.24	537.6	258.8	896	45.23	22.03	20..19
Kitchen waste	7.33	2.90	1531.2	208.1	1,740	49.81	14.13	17.18
Oil palm sludge + oil palm waste	6.97	1.40	492.0	98.0	392	39.30	32.25	28.07
Sewage sludge	5.01	4.00	1650.0	1,350	3,000	46.00	20.70	11.50

Table 3: Amount of N mineralization with successive incubation period in waste amended wetland soil.

		N Mineralized with successive incubation period (day) specified ($mgkg^{-1}$)				
Soil	**Waste**	**0-14**	**14-28**	**28-42**	**42-56**	**Total**
Fadamal soil	Cow manure	0	62.20	4.69	15.26	82.15
	Poultry manure	0	76.97	38.48	19:25	134.7
	Kitchen waste	0	130.73	57.00	28.42	216.15
	Oil palm waste	0	60.30	7.38	25.5	93.27
	Sewage sludge	0	176.00	70.4	35.2	281.60
	Control	0	3.0	2.0	2.0	3.50
Meander Belt soil	Cow manure	0	27.25	18.17	9.08	54.0
	Poultry waste	0	62.4	32.2	15.6	109.2
	Kitchen waste	22.41	0.00	134.48	22.41	179.3
	Oil palm waste	0	49.04	23.48	12.04	84.56
	Sewage sludge	0	121.21	0.97	46.55	168.78
	Control	0	3.0	2.0	4.0	3.0
Mangrove swamp soil (mangal acid-sulphate soil)	Cow manure	0	64.88	22.44	11.22	98.50
	Poultry waste	0	99.39	0	38.97	138.36
	Kitchen waste	0	130.5	1.31	127.89	259.7
	Oil palm waste	0	49.93	17.46	13.95	81.34
	Sewage sludge	0	2.92	28.0	0	320.00
	Control	0	4.0	3.0	4.0	5.0

Table 3 presents the amount of nitrogen mineralized compared with the successive incubation in the waste amended wetland soils. A shown in table III, no mineralization took place within the first 2 weeks of incubation, except for meander belt soil amended with kitchen waste. The nitrogen mineralized during 58 days incubation ranged from 82.15 $mgkg^{-1}$ to 281.60 $mgkg^{-1}$ for fadamal soil, 54.50 $mgkg^{-1}$ to 197.30 $mgkg^{-1}$ for meander belt soil and 98.50 $mgkg^{-1}$ to 320.00 $mgkg^{-1}$ for mangrove swamp soil. The order of cumulative nitrogen released in the waste amended soils follow the order; sewage sludge>kitchen waste> poultry manure>oil palm waste>cow manure. This contrasts the order of C:N ratio of the waste used for the incubation. This is due to the fact that when stabilized organic products with adequate C:N ratio (<20) are added to the soil, the mineralization process is enhanced (Nogales *et al*., 1982) while products with high C/N ratio promotes immobilization (Stemmer *et al.,* 1999). The promotion of nitrogen immobilization or reduction of nitrogen mineralization by high C:N ratio waste is as a result of the increase in microbial load stimulated by high carbon content. This make such organisms to consume most of the nitrogen meant for mineralization for their own body activity (Brady, 1974).

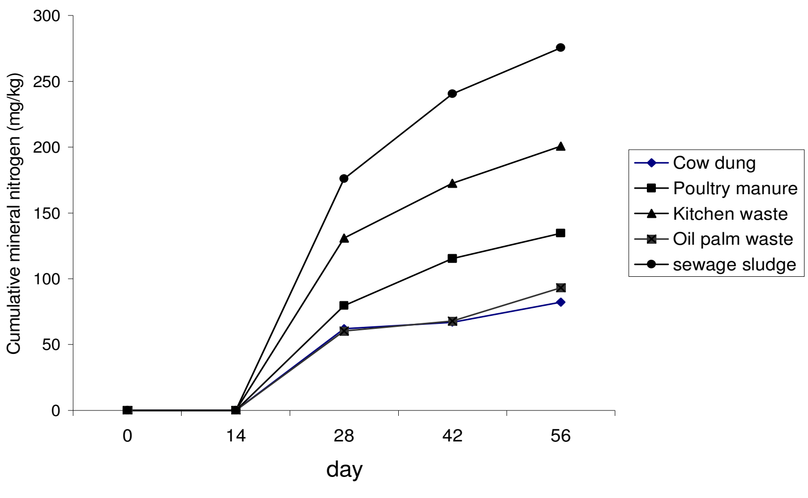

Fig 1: Cumulative nitrogen mineralization in fadamal soils amended with organic wastes.

The mangrove soil (mangal acid-sulphate soil) and fadamal soil showed higher amount nitrogen released compared to the meander belt soil. This due to the high proportion of the sand fraction in these soils.

Our finding agrees with observations of Madrid *et al*. (2001) who observed that nitrogen mineralization is by far more intense in the sandy soil than clay soil when the soils are amended with municipal waste sludge composts. Higher protection of the organic matter-clay complex makes microbial attack in soil with high clay contents more difficult (Herbert *et al*., 1991).

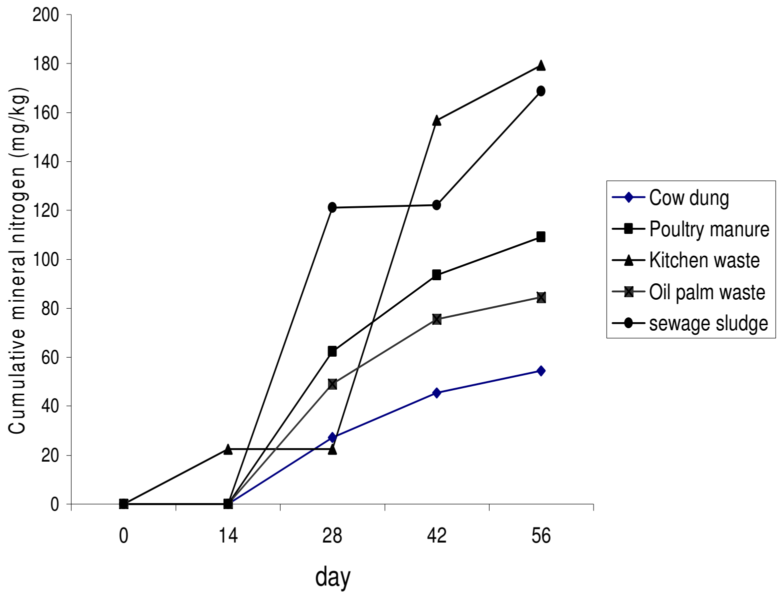

Fig 2: Cumulative nitrogen mineralization in meander belt soil amended with organic wastes

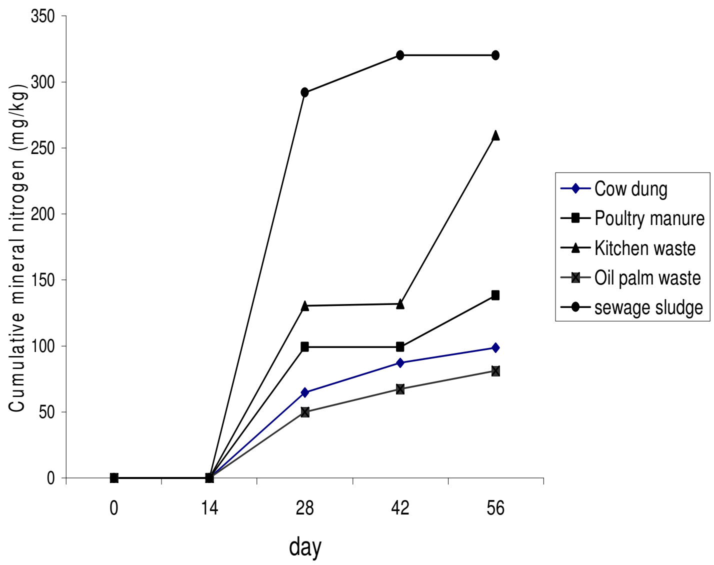

Fig 3: Cumulative nitrogen mineralization in mangal acid sulphate soil amended with organic wastes

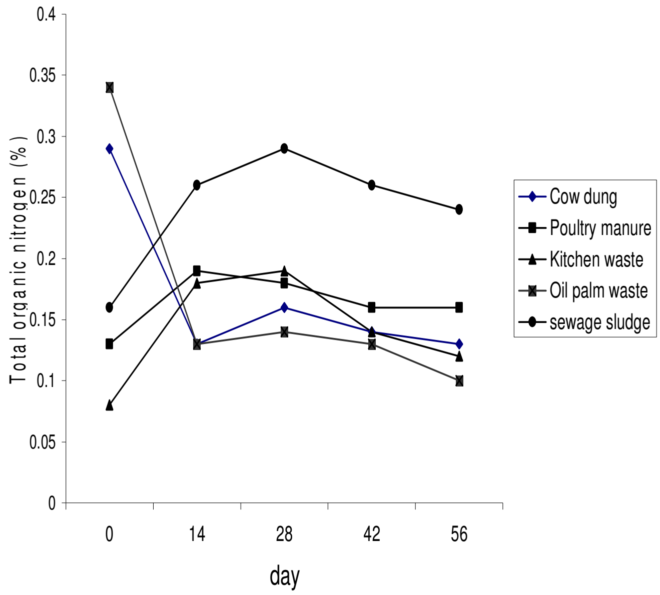

Fig 4a: Changes in total organic nitrogen in fadamal soil amended with organic wastes

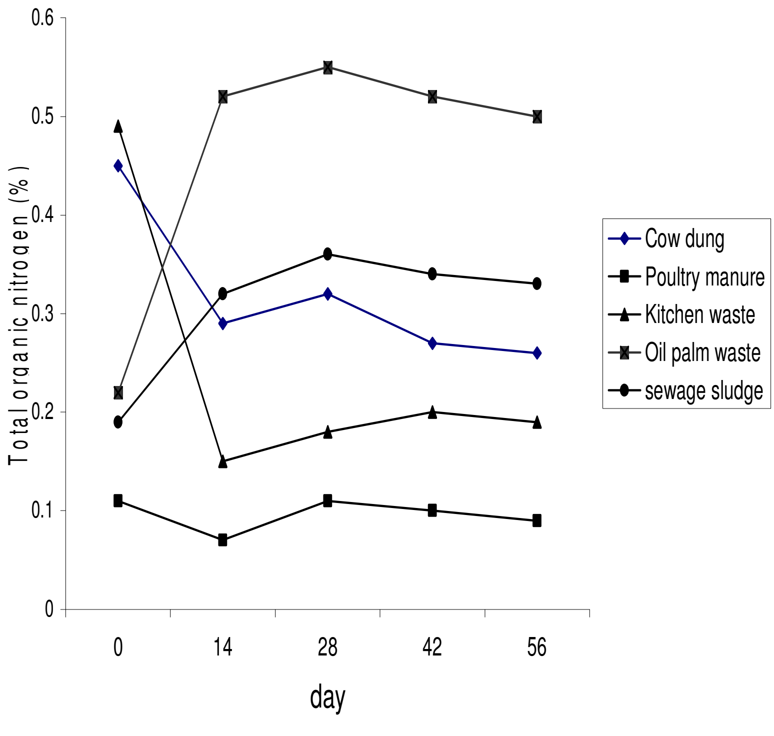

Fig 4b: Changes in total organic nitrogen in meander belt soil amended with organic wastes

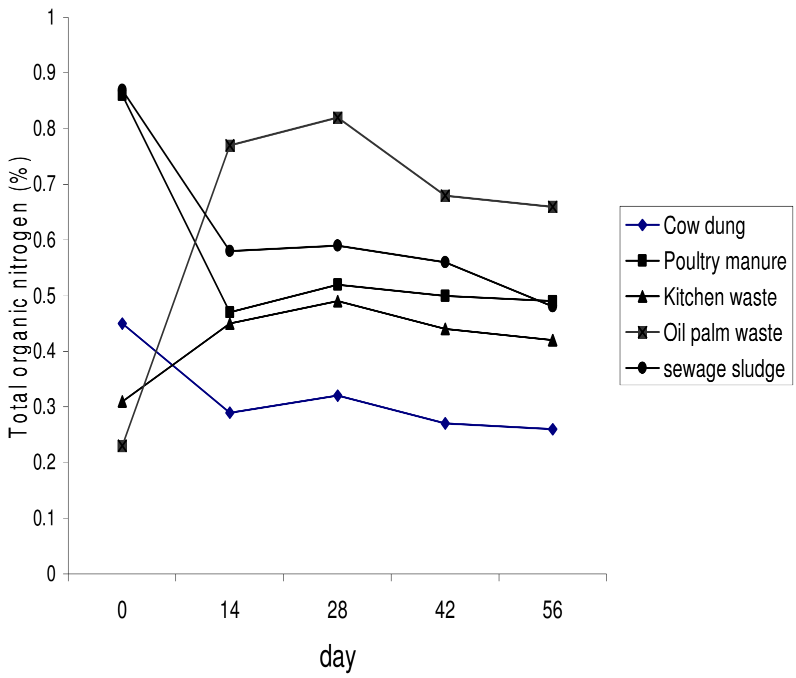

Fig.4b: Changes in total organic nitrogen in mangal acid sulphate soil amended with organic wastes.

Chae and Tabatabai (1986) have also reported low mineralization value for fresh cattle manure in soil; the manure used was probably mixed with urine. They found about 1.4% mineralization of organic nitrogen after 8 weeks with figure increasing to 13% after a long-term incubation. Similarly in this study cow manure showed the least value of nitrogen mineralization.

Figures 4a, 4b, 4c illustrates the changes in total organic nitrogen with respect to incubation time for fadamal, meander belt soil, and mangal acid-sulphate soil respectively. There was a marked decrease in the total organic nitrogen during the incubation period. The changes in the total organic nitrogen after 28 days reflect increased conversion of organic nitrogen to inorganic forms as a result of increased microbial activities (Brady, 1974). The decrease in total organic over incubation period showed a remarkable difference among the various soil and waste types. This is due to the differences in the physicochemical properties of the different soil and wastes. Total organic nitrogen and C:N ratio showed negative significant correlation with nitrogen mineralized ($P \geq 0.05$ r = -0.33 and r = 0.92, respectively)

The results obtained indicate that N mineralization in organic waste-treated soil is highly dependent on the composition of the organic waste and the chemical and physical make up of the soil receiving the organic waste.

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