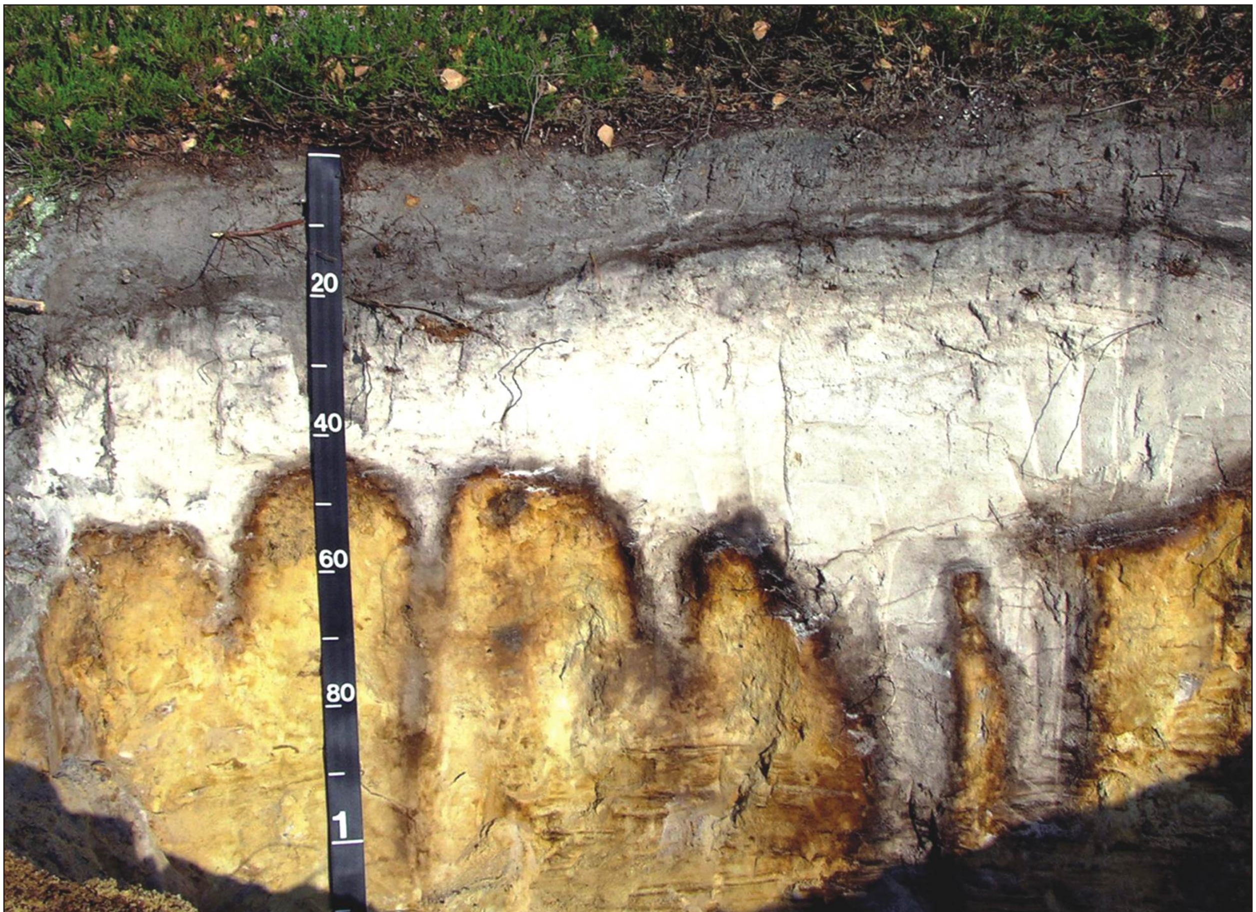


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# Mineralization of Nitrogen in Wetland Soils of the Niger Delta Amended with Water Hyacinth (*Eichhornia* sp.) Waste

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**Abstract:** This study presents the results of Nitrogen mineralization in wetland soils of the Niger Delta amended with water hyacinth waste. In this work, field-moist soils amended with water hyacinth waste at a rate of 40 t $ha^{-1}$ were extracted with 2M KCl to remove mineral nitrogen. The extraction procedure was repeated every two weeks for a total of 8 weeks. The extract was analyzed for ($NH_4$-N + $NO_3$ - N). The mineralization of N exhibited a slow initial rate, which was indication of lag period, followed by a rapid increase in rates and subsequent slow rate of N released. The total amount of Nitrogen released in the three soils at 56 days were 486.69, 352.37 and 422.87 mg $kg^{-1}$ for fadamal soil, meander belt soil and mangal acid-sulphate soils respectively. Total organic nitrogen decreased with incubation time. At the end of 56 days 67, 31.3 and 36% of the total organic nitrogen in fadamal soil, enitsol and mangal acidic sulphate soil respectively was converted into inorganic nitrogen. Soil types have marked effects on nitrogen mineralization. The order mineralization of nitrogen in the soils follow the order: fadamal soil>Entisol>mangal acid sulphate soils. This is indicative of the fact that water hyacinth waste is a good substitute for chemical fertilizer in soils.

**Key words:** Nitrogen mineralization, nitrogen immobilization, mineralization rate, water hyacinth waste, wetland soils, Niger Delta

## Introduction

The important problem of water hyacinth (*Eichhornia* sp.) growing in rivers and creeks is well known. In the Niger Delta, *Eichhornia crapsipse* is the species which cover the rivers and creeks.

The removal of the water hyacinth plants by hand or mechanical means which is the usual practice in the Niger Delta is costly, furthermore, the removed plants are usually left on the banks to create other problems. Water hyacinth seem to be a good source of organic matter and nitrogen and may be used as composts to meet the great demand for organic manure, particularly in the Niger Delta. This practice may offset the cost of the river and creek clearing process. The water hyacinth contains essential plant nutrients, primarily nitrogen and phosphorus. The organic matter in water hyacinth is a key component to its success as an organic amendment. The water hyacinth waste is a convenient amendment because it has many fertilizer constituent in one application.

Restoring nitrogen cycling is one of the major goals of ecosystem recovery of soils in wetland areas, whether they are returned to natural habitats or agricultural enterprise. Because opposing N transformations occurs simultaneously, estimates of N cycling processes base on net changes of N substrates and product are unlikely to provide a clear indication of the impact of soil restoration practices in wetland area of the Niger Delta.

The wetland soils especially are not particularly cultivated because of the assumed poor soil quality. Researches have been focused on the intensively managed agricultural and forest soils-but

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attention has be paid to the concept and importance of soil quality that is pertinent to disturbed systems such as the wetland soils. The restoration of soil functions and soil quality are essential to long-term ecosystem stability.

Of many of the problems associated with organic farming and various soil management practices, including minimum and no-till systems, nutrient cycling in organic wastes treated soils deserved attention. Information on the degree of nutrient released (mineralization) and nutrient tie up (immobilization) in wetland soils treated with various organic with various organic waste materials therefore are needed. Mineralization of nitrogen waste material is dependent on the chemical and physical characteristics of the waste material as well as those of the soil receiving the waste materials (Chae and Tabatabai, 1986). Information on N mineralization in the various soil-organic systems is needed for better prediction of crop Nitrogen requirement (El-Haris *et al*., 1983; Chae and Tabatabai, 1986). The dynamics of nitrogen mineralization of organic wastes have been described with first order reaction kinetics (Chae and Tabatabai, 1986; Cheschair *et al*., 1986; Murwira and Kirchman 1993; Christensen and Olesen, 1998) or a set of first order reaction kinetics (Gale and Gilmour, 1986). The specific objective of this study was to determine the ability of water hyacinth waste amendment to improve wetland soil quality as measured by nitrogen mineralization.

## Materials and Methods

Three surface soils (0-15 cm) (Table 1) selected to represent some major soil series in the Niger Delta Nigeria and include a wide range of chemical and physical properties. Samples of field-moist soils were brought to the laboratory, passed through a 2 mm screen and divided into two portions. One was placed in a polyethylene bag and stored in a refrigerator at 4°C and a subsample of this portion was used in the incubation experiment to study mineralization of nitrogen. The incubation experiment was carried out in June-July 2005. The second portion was air-dried at room temperature for 48 h and stored in a tightly sealed bottle. A subsample of the air dried portion was used for determination of chemical properties (Chae and Tabatabai, 1986).

The water hyacinth used was collected from the Warri River Nigeria. The water hyacinth samples were oven-dried for 3 days at 65°C and ground to pass a 20-mesh sieve (850 µm). The water hyacinth samples were stored in glass bottle at 4°C. In the analyses reported in Table 1 and 2, pH was determined by glass electrode (soil/water 1:2.5 and plant material water ratio 1:10) (Mclean, 1982). Total organic carbon was determined by the wet dichromate method of the Walkley and Black (Nelson

Table 1: Physicochemical properties of the Niger Delta soils used

| Samples | pH | Total organic C (%) | Total (%) | NH4$^+$ (mg kg$^{-1}$) | $NO_3^-$ (mg kg$^{-1}$) | Total Min N | C/N | Ash content (%) | Sand | Silt | Clay | Texture |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fadamal soil | 7.16 | 1.73 | 0.06 | 5.25 | 9.75 | 15.00 | 28.83 | 87.47 | 87.47 | 5.01 | 7.52 | Sand |
| Meander belt soil (Enitsol) | 6.31 | 5.24 | 0.13 | 4.68 | 10.95 | 15.60 | 40.31 | 49.85 | 49.85 | 25.08 | 25.08 | Sandy clay loam |
| Mangal acid sulphate soil | 6.16 | 12.76 | 0.50 | 40.00 | 60.00 | 100.00 | 25.48 | 55.74 | 55.74 | 11.07 | 33.00 | Sand clay loam |

Table 2: Physicochemical properties of the water hyacinth waste

| Parameters | Mean value |
|---|---|
| pH | 8.50 |
| Total-N (%) | 1.90 |
| $NH_3$-N (mg kg$^{-1}$) | 846.45 |
| $NO_3$-N (mg kg$^{-1}$) | 198.55 |
| Total Min-N (mg kg$^{-1}$) | 1,045.00 |
| TOC (%) | 36.36 |
| C/N | 19.12 |

* Mean of triplicate analysis RSD less than 5%

and Sommer, 1982). Total nitrogen was determined by using the total Kjeldahl method (Bremner and Mulvaney, 1982). Mineral N was determined by colorimetric method (Keeney and Nelson, 1982) after extraction with 2M KCl. The particle size distribution was determined by the hydrometer method for silt and clay and by dry sieving for sand fraction (Reeuwijk, 1995).

The incubation experiment was done in the laboratory at field capacity and at constant temperature of 25°C. Soil samples (each 10 g) were thoroughly mixed with 200 mg dry weight (equivalent to 40 tones per hectare) of water hyacinth waste and place in 100 mL incubation vessel. Samples for inorganic nitrogen were taken at day 0, 6, 14, 28, 42 and 56. Total inorganic nitrogen mineralized during incubation was determined after extraction with 2M KCl by procedure earlier described.

## Results and Discussion

The manner in which N is mineralized during incubation follows one of the following (i) immobilization of nitrogen during the initial period of incubation, followed by mineralization in the later period (ii) rate of release decrease with time (iii) a steady linear release with time over entire period (Tabatabai and Alkhafaji, 1980; Chae and Tabatabai, 1986). The total mineral nitrogen wetland soils amended with organic waste are presented in Fig. 1.

The pattern and amount of N mineralization from organic material depend on the nature of the waste and soil to which the waste material are been added. The cumulative amount of N mineralized in Fadamal Soil (FS), meander belt soil (Entisol) and acid sulphate mangrove swamp soil (NS) treated with water hyacinth waste are plotted in Fig. 2. The results obtained for physical and chemical

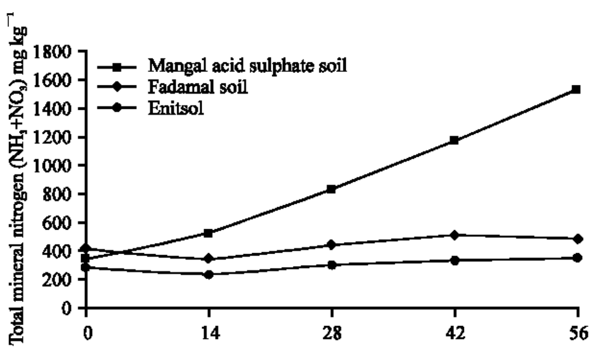


Fig. 1: Total mineral nitrogen in wetland soils amended with water hyacinth waste

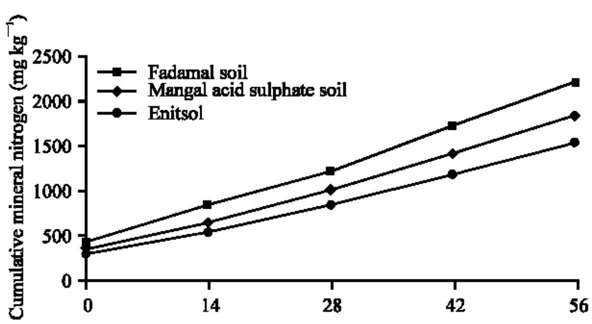


Fig. 2: Cumulative N-mineralization at optimal moisture in water hyacinth waste amended wetland soil

characteristics of the soils and waste are shown in Table 1 and 2, respectively. In general, the N mineralization in water hyacinth treated soils show a slow initial released, which is an indication of the lag period, followed by a rapid increase in N mineralization. The initial mineralization pattern differed markedly among the different soils. The cumulative nitrogen released in three soils at 56 days was 2206.4, 1526.60 and 1828.80 mg $kg^{-1}$ for fadamal soil, entisol and mangal acid-sulphate soil respectively. The fadamal soil gave the highest amount of cumulative mineral nitrogen released within the period of incubation compared to Enitsol and mangal acid-sulphate soils. The amount of total mineral nitrogen released in the three soils at 56 days were 486.69, 352.37.37 and 422.87 mg $kg^{-1}$ for fadamal soil, meander belt soil (Entisol) and acid sulphate soil respectively (Fig. 1). The amount of nitrogen released in our study is higher than amount of nitrogen released reported by Chae and Tabatabai (1986) and Pettygrove *et al*. (2003).

The water hyacinth waste treated showed initial N immobilization of 13, 16 and 16% within the first 14 days for fadamal soil, meander belt soil and acid sulphate soils respectively. Van Kessel and Reeves (2000) reported that an aerobic incubation study 107 manures ranging from 1.4 to 3.9% solids, results ranged from a net N mineralization of 55% to a net immobilization of 29% of the organic nitrogen. They also concluded that manure composition e.g., C:N ratio, organic N and lignin, was not helpful in explaining the results. It is possible that the residence time or properties related to it such as percent volatile solids, degree of humification, etc. might be related to the potential mineralization rate. However, in present study the immobilization of nitrogen at the initial stage of incubation is due to high CN ratio of the waste and intense microbial activity. Thereafter, a rapid increase in the percent organic nitrogen mineralized. For example, in fadamal soil the percentage of nitrogen mineralized is 5.4, 21.7 and 16.4% at 4, 6 and 8 weeks, respectively. The percentage of nitrogen mineralized was highest at 6 weeks in all soils and thereafter declined in the percentage of nitrogen mineralized. Similarly, Pettygrove *et al*. (2003) reported that Net mineralization was rapid during the first 21 days and was slow and variable thereafter, apparent net mineralization during the first 21 days averaged 15-20% of applied manure organic nitrogen. The percentage nitrogen mineralized in our study is higher than 1.4% mineralization of organic nitrogen after 8 weeks with the figure increasing to 13% after a long term incubation of 28 weeks (Chae and Tabatabai, 1986). The result reported by Castellanos and Pratt, (1981) also show low N mineraization of 5-8% organic nitrogen in composted dairy manure after incubation for 10 weeks in the laboratory. Analysis of variance (ANOVA) ($p \geq 0.05$) shows that there was no significant difference in the percentage of percent of inorganic nitrogen released in the Enitisol and acid sulphate soil. However, a significant difference was observed when Entisol or acid sulphate soil is compared with fadamal soil. This indicative of the fact that mineralization of nitrogen depend on waste type and textural characteristic of the soil (Mertin-olmed *et al*., 1995). Soils with similar textural characteristics show similar pattern of percent of inorganic nitrogen released (Meander belt soil and acid-sulphate soils). The mineralization of nitrogen is in the following order fadamal soil>entisol>mangal acid-sulphate soil. The present finding agrees with the observation of Madrid *et al*. (2001) that observed that nitrogen mineralization is by far more intense in sandy soils than in clay soils when such soil is amended with municipal waste sludge composts. Higher protection of the organic matter by humus-clay complex make microbial attack in soil with clay content more difficult (Herbert *et al*., 1991). Sorenson (1975) found that the decomposition of labeled cellulose was faster in a sandy soil than in a soil with appreciable 2:1 clay. He concluded that the amount of microbial biomass and metabolites form during the first phase of decomposition process is greatly influenced by soil texture, with clay soil retaining more than sandy soils.

The mineralization rate constant Kr was computed by fitting into this equation $Nm = No\,[1-\exp(-kt)]$. The rate constant Kr were 0.025 and 0.026 $week^{-1}$ for fadamal soil, enitsol and mangal acid sulphate soil respectively. The mineralization rate constant we obtained from our study is lower than Kr values reported for Alfalfa amended soils by Chae and Tabatabai, (1986). Total organic

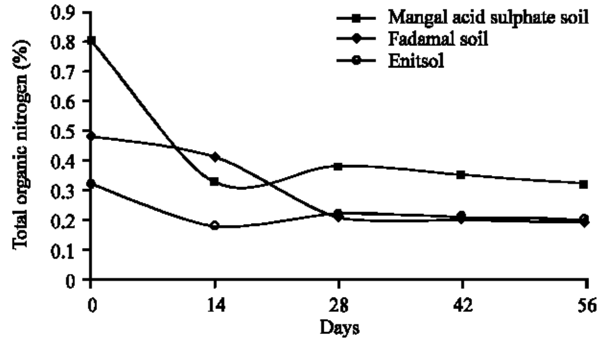


Fig. 3: Changes in the levels of total organic N in wetland soil amended with water hyacinth waste

nitrogen decreased over incubation time (Fig. 3). Obvious decrease was observed after 28 days. The decrease in total organic nitrogen could be attributed to increased conversion of organic nitrogen to inorganic nitrogen as result of increased microbial activities during this period. At the end of 56 days, 67, 31 and 36% of the total organic nitrogen in fadamal, meander belt and mangal acid sulphate soils respectively have been converted into inorganic nitrogen. The decrease in total organic nitrogen with incubation was highest in fadamal soil compared with meander belt soil and acid sulphate magrove swamp soil.

The results obtained indicate that Nitrogen mineralization in organic waste-treated soil is highly dependent on the composition of the waste and the chemical and physical characteristics of the soil receiving the organic wastes. Water hyacinth waste stands the chance as good substitute for chemical fertilizer in wetland soils in that the waste contains essential plant nutrients; the rate at which nitrogen mineralized is rapid and gave improved soil quality within a short period of application.

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