Acid Sulfate Soils of the Mangrove Swamps of Rivers State, Nigeria

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Introduction

The mangrove swamps of southern Nigeria form the transition zone between the coastal waters bordering Nigeria to the south and the forested fresh-water swamps to the north. The quality and quantity of the forest products (e.g. timber, fibers, etc.) of southern Nigeria are affected by the ecology of the mangrove swamps with specific reference to the physical and chemical properties of the soils. The mangrove soils and wetland soils are probably comparable in general structure and outlay with the wetlands of the Mississippi delta or those of the Ganges delta in India.

The soils of the mangrove swamp of southern Nigeria have only been studied in recent years. The neglect of their study prior to recent times was probably because navigation through the creeks and channels is a risky and difficult undertaking as sandbars make navigation difficult, and salt water crocodiles (*Crocodylus prosus*) abound. Recently, ecologists with determination and seriousness of purpose, have ventured to study the mangrove swamps, their management and potential uses.

Materials and Methods

Soils of the tidal brackish-water swamps and salt-water tidal mangrove swamps were investigated. The sites of investigations were the mangrove swamps of Brass (4°42′ N, 6°17′ E) and Degema (4°45′ N, 6°47′ E) all in the Niger Delta. The annual rainfall at Degema is about 2,022mm and the mean annual temperature is about 26°C; Brass has an annual rainfall of 3,120mm. Pedons representative of different soil types were dug, described and analyzed. Because of the need to retain the natural state of the soils and to prevent oxidation during transportation, each sample was collected in a black polyethylene bag. In the laboratory, a subsample of each soil sample was taken for pH determination in the wet state while another subsample was air-dried for about 15 days. The dried subsample was gently crushed in a mortar and sieved with a 2-mm sieve. Particles retained on the seive were discarded while those which passed through were used for the following analyses: particle size—by the modified hydrometer method (9); pH in water and $CaCl_2$ using the glass electrode pH meter; total nitrogen by the microkjeldahl method; total organic carbon by the Walkey Black oxidation method as described by Allison (1) and chemical analysis of total water soluble elements, exchangeable cations, free or reactive ions and structurally bound elements determined sequentially by the modified methods of Khalid (5) and Chao and Zhou (4).

Results and Discussion

Within the mangrove tidal wetlands are presently recognized and classified Histosols including Sapric Tropohemists, Typic Sulfihemists and (Fibric) Sulfihemists (12).

Soil Morphology

It was observed that in both the tidal brackish-water and tidal salt-water mangrove swamps, the soils were fibrous, spongy peats undergoing different stages of development. They were also composed of soft mangrove fibers easily destroyed by rubbing between the thumb and fingers. Hemists and Fibrists were common peats while Saprists appeared restricted to the elevated edge of tidal flats with fresh mud regularly deposited by tidal or flood water. The surface horizon of the peats was fibric while the subsurface horizon included varied proportions of fibric, hemic and hemic with some sapric material. No clear pattern of mineral matter entrapped by the mangrove roots was established.

Water Holding Capacity of Mangrove Soils

The peats were sandy clay loam in texture. The water saturation varied from 36-70% and was related to the total organic matter content of the soils. The total organic matter of the soils varied from 10-54% (Table 1). Table 2 shows some chemical characteristics

TABLE 1. Physical characteristics of mangrove swamp soils in Nigeria.

Environment	Location (Pedon)	Horizon & Depth (cm)	Water Saturation %	Total Organic Matter, %	Soil Classification
Tidal	Oboibiri,	00-20	66.0	n.a.	Sapric
brackish water	Brass	20-40	54.8	26.1	Tropohemist
mangrove swamp		40-70	n.a.	28.1	
	Sabatoru,	00-15	48.2	20.9	Sapric
	Nembe	15-30	36.6	12.7	Sulfihemist
		30-60	36.0	10.0	
	Ogonokun	00-25	n.a.	n.a.	Typic
	near Degema	50-75	n.a.	22.9	Sulfihemist
		75-100	n.a.	26.4	
Tidal	Nembe	00-30	38.7	n.a.	Fibric
salt water	Creek	30-50	42.5	23.3	Sulfihemist
mangrove swamp	Site 3	50-80	39.6	23.7	
	Nembe	00-25	51.5	31.6	Typic
	Creek	25-35	70.4	54.2	Sulfihemist
	Site 1	35-50	65.0	49.5	
		50-70	58.3	n.a.	

n.a. = Data not available

of mangrove soils. The amount of humified matter was low, varying from 1.83-4.65% and suggesting a low rate of humification of organic material under the prevailing anaerobic conditions. Soils of the salt water swamps had the largest amount of total organic matter. Probably, the large amounts of excess salts in the latter soils prevent microbial activity and expected mineralization of organic matter.

Soil pH

In the wet state, soil pH was between 4.7 and 7.0 but on drying soil pH dropped drastically to less than 4.0 in most soils (Table 2). This drop in pH showed that the peat soils have a tendency to develop extreme acidity on oxidation owing to the presence of sulfidic or pyritic materials capable of releasing appreciable amounts of sulfuric acid through chemical or biological oxidation (3,10). The pungent odor usually emanated from the mangrove swamp soils originates from the release of hydrogen sulphide under anaerobic conditions.

Macronutrient Status of Soils

Total N was relatively higher than in the non-organic or well-drained soils of the same environment.

TABLE 2. Chemical characteristics of mangrove swamp soils in Nigeria.

Profile (Pedon)	Depth (cm)	pH Wet	pH Dry	Total N %	Organic C %	Avail. P (ppm)	E S P
	Sapric Tropohemist						
1	00-20	5.1	4.6	0.12	4.03	n.a.	10.7
	20-40	5.3	4.2	0.34	4.04	2.8	16.5
	40-70	4.7	4.0	0.31	4.05	n.a.	6.6
	Typic Sulfihemist (Saline phase)						
2	00-15	6.2	3.1	0.24	3.71	1.6	6.0
	15-30	6.0	3.1	0.08	2.32	1.8	11.4
	30-60	6.8	3.6	0.07	1.93	2.4	14.2
	Typic Sulfihemist (Saline-sodic phase)						
3	00-30	5.5	2.7	0.29	3.82	2.3	57.7
	30-60	6.7	3.4	0.07	2.69	2.3	39.8
	60-90	7.0	4.7	0.06	1.83	n.a.	40.9
	(Fibric) Sulfihemist (saline-sodic phase)						
4	00-30	5.5	2.0	0.35	4.34	3.4	21.2
	30-50	5.5	2.5	0.31	4.43	n.a.	23.7
	50-90	6.2	4.0	0.71	4.65	n.a.	35.2
	(Sapric) Sulfihemist (saline-sodic phase)						
5	00-25	6.1	3.4	0.35	3.95	2.0	26.2
	25-35	5.0	1.9	0.34	4.08	n.a.	n.a.
	35-50	5.9	2.3	0.40	4.28	n.a.	39.6
	50-90	5.0	2.5	0.28	4.14	n.a.	n.a.

ESP = Exchangeable Sodium Percentage
n.a. = Data not available

The range of 0.06-0.71% indicated the high N supplying potential of the mangrove swamp soils. Available P was quite low, in the range of 1.6-3.4 ppm. Water soluble Mg (Table 3) was the highest (101 ppm) among the macronutrients while P was the lowest (9 ppm). About 19% total sulfur was detected in these soils. Among the exchangeable cations, K was the lowest while Mg was the highest. The structurally bound concentrations of the macronutrients were in the order of P > Mg > K > Ca while the reactive mobile ions were in the order of P > Mg > Ca > K. These results were in agreement

TABLE 3. Elemental ions - constituents of surface soils of the mangrove swamps in Nigeria.

Element	Water Soluble (ppm)	Exchangeable Cations (ppm)	Structurally Bound Crystalline (ppm)	Reactive Mobile Ions (ppm)
P	9	7	295	25
K	10	2	29	1
Ca	37	18	3	9
Mg	101	43	62	11
Al	68	21	34,165	692
Fe	699	88	16,785	685
Mn	9	3	96	3
Si	403	28	206	133

with those of Sposito (13) who reported that relatively higher amounts of macro-solute metal ions appeared to be present in organic soils of brackish-water swamps.

The exchangeable sodium percentage (ESP) ranged from 6.0-57.7 (Table 2). The presence of appreciable amounts of Na on the exchange site was indicative of the presence of sulfates and carbonates of sodium active in alkaline hydrolysis.

Other Nutrients

The concentration of both water soluble and exchangeable cations followed the same trend and was in the order of Fe > Si > Al > Mn. Similarly, the structurally bound (crystalline) and reactive mobile ions both followed the same trend in the order of Al > Fe > Si > Mn. The results were consistent with earlier observations of Schwertmann (11), Nordstrom (7) and Chao and Zhou (4) who reported that two dominant elements in mobile reaction state in wetland soil suspension (1:9 soil water) were Al and Fe existing possibly as free oxyhydrates or organometal complexes. The high amounts of structurally bound Al and Fe indicated the presence of alumino silicates which could be weathered readily to release the elements.

The presence of S and Fe appeared to be a factor in the development of potential acid sulfate property in the mangrove swamp soils.

Agricultural Implications

The need for the reclamation of the mangrove swamp soils had been earlier advocated and their potentialities highlighted (2,8). If the fresh water mangrove swamps are reclaimed and the soils amended, it is possible to use them for improved fishery and for the cultivation of such crops as swamp rice, pineapples, cassava, water yams and vegetables. Cash crops such as oil-palm and coconut can be grown also. Forestry products can be obtained from the mangrove swamps if the potentials of *Nypa fruticans*, *Raphia* species and *Alchornea cordifolia* are adequately exploited.

However, other than the huge cost of reclamation of the soils, several management problems have to be solved. The greatest of these is ion toxicity (to plants) arising primarily from a high level of exchangeable Al. Excess soluble salts as well as the Ca/Mg imbalance would also present a major problem. Extreme acidity non-conducive to good plant growth is bound to develop on exposure of the soils to oxidation which must be countered by soil management, often an expensive venture in this regard. The problem of alkaline hydrolysis may result in soil dispersion and creation of unfavorable soil structure. Subsidence of the peat soils on rapid weathering following exposure and due to their conversion from fibric to sapric state will have to be contended with.

In using the mangrove swamps for forestry and agricultural purposes, it should be stressed that plant adaptation must be the guiding principle. Some plants are known to have the ability to grow in soils which contain levels of toxic ions lethal to other species. Those species which resist ion toxicity are found to use one or a combination of four mechanisms: tolerance, phenological escape, exclusion and amelioration. The swamp rice plant, for example, has been observed to oxidize Fe^{2+} to Fe^{3+} by oxygen excretion (a type of phenological escape by direct environmental modification) from the roots, so avoiding Fe^{2+} toxicity (14). Tal (15) observed that cultivated tomatoes (*Lycopersicon esculentum*) absorbed less Na^{+} and Cl^{-} when grown under high salinity than the wild *L. peruvianum*, with adverse effects on both relative water content and growth rate. *Avicenia africana* (white mangrove) and *A. nitida* reduce salt concentration by excretion while *Rhizophora racemosa* (red mangrove) reduces it by exclusion (6). To lessen the problems of ionic toxicity in the mangrove swamp soils, other than drainage and liming, flood protection measures and control of water table will be needed.

Conclusion

Despite the high levels of toxic ions and high potential acidity in the mangrove swamp soils, their high water holding capacity, nutrient levels and organic matter contents suggest that these soils can be used for agricultural, forestry and fishery purposes if increased classification and characterization work and massive investments are made for land reclamation and soil amendments, using improved planting material including adaptive species.

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