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Genesis, Classification and Heavy Metal Retention Potential of Soils in Mangrove Forest, Niger Delta, Nigeria

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ABSTRACT Soils under the main mangrove {*Rhizophora racemosa* and *Avicennia germinans*} forest in the Niger Delta, Nigeria were characterized and their capacities to retain heavy metals were examined using soil column leaching experiments. At the end of the leaching experiments, soil samples from each column were divided into two: 0-5 cm and 5-10 cm, and analyzed for total metal retained. The fractionation of heavy metals in the surface soil samples (0-5 cm) was investigated by the sequential extraction technique. The study showed that the soils were influenced by tidal flow and characterized by the presence of very fine textured, thin (0 – 5 cm) to moderately thick (10 – 15 cm) layer of alluvium (mud) on the surface. The fibric soil material beneath the surface mud varies in thickness from about 70 to 100 cm, and beyond the histic layer is the plastic, very sticky, massive clay. *In situ*, the soils were neutral in reaction (pH, 7.0 to 7.2) but became strongly acid (pH, 3.3 – 4.8) upon drying. They are saline, high in soluble salts, highly reduced, with low CEC in the fibric layer but high in the mineral, clayey subsoil horizon. The soils are saturated with water for much more than 30 days in a year and have fibre content that is more than 40-cm thick, with the fibric sphagnum constituting more than three – fourths by volume to a depth greater than 90 cm. The soils, classified as Typic Sphagnofibrists, sequested considerable amounts of Cu, Zn, Cd, and Mn with most of the metals retained in the surface soils. The anthropogenic heavy metals were mostly adsorbed probably to the negatively charged sites of organics and clay. These loosely-bound metals may be desorbed and re-enter the aqueous phase, thus becoming a secondary source of metal pollution to the fauna and man in the environment.

INTRODUCTION

Mangrove forest, a complex intertidal ecosystem distributed in the tropics and subtropics, forms the major habitat type in the Niger Delta, Nigeria. The forest covers approximately 6000 km^2 land-area in the southern part of Nigeria. The mangrove swamps have traditionally been neglected by pedologists for various reasons. They are generally inaccessible, inhospitable, and of minimal agricultural value (Coultas and Calhoun, 1976). The zone has generally been relegated for use as a wildlife habitat and recrea-tional areas (Rutledge, 1973), propagation and development of many marine organisms (Heald and Odum, 1969), erosion protection and habitat for migratory birds (Coultas and Calhoun, 1976). With increasing population pressure and industrial growth, the mangrove forest areas are assuming greater importance as a land resource. In Nigeria for instance, most of the richest oil wells are located within this habitat (Moffat and Linden, 1995). The ecosystem is periodically flooded by incoming and outgoing tides and therefore the industrial discharge of aqueous effluents into creeks and canals in the region can readily get onto the land areas when mixed with the tidal flow. Though mangrove soils are reported to possess a remarkable capacity to retain heavy metals (Dwivedi and Padmakumar, 1983; Chen and Lin, 1988; Tam and Wong, 1993), but can also be sources of contamination. It has been argued that the metals may only be accumulated temporarily and will be re-mobilized/re-suspended back to the water column and become a secondary source of pollution. The adsorption and desorption of heavy metals in wetland soils depend on one or a combination of soil properties including pH, CEC, organic matter, clay content, redox potential, salinity, iron and manganese oxides, presence of other metals, the quantity of heavy metals accumulated, and the alternating aerobic and anoxic conditions, among others (DeBustamante, 1990; Harter, 1992; Kerner and Wallmann, 1992; Orson et al., 1992; Tam and Wong, 1996). Like other wetland soils, the adsorption and mobilization of heavy metals in mangrove ecosystem is highly dependent on their physical and chemical conditions (Harbison, 1986; Lacerda et al., 1993). The present study therefore was aimed at detailed characterization of soils in the mangrove ecosystem and the assessment of the ability of the soils to retain heavy metals.

MATERIALS AND METHODS

The Study Area: In Nigeria, the three (red, white and black) main types of mangrove exist, all occupying about 6000 km^2 of land area (Moffat and Linden, 1995). Two species of *Rhizophora* (*R. racemosa* and *R. mangle*) predominate with about 90% being *R. racemosa*. The different mangrove types are often mixed together in a stand with *Rhizophora* sp. tending to fringe waterfronts while *Avicennia germinans* are found in slightly higher elevations (Anderson, 1967). The third type, *Laguncularia racemosa*, is not restricted to specific physiographic position of the ecosystem. The Niger Delta is characterized by the wet (March- October) and dry (November – February) seasons. Most (about 80%) of the total annual rainfall is recorded between June and September although Anderson (1967) noted that there was no month without at least 25 mm of rainfall. Annual total rainfall is about 2,500 mm and average wind speed is 2.7 m/s in a predominantly southwest (SW) direction. Relative humidity is high throughout the year averaging about 85% and with high air temperature ranging between 20 and 35^{0}C throughout the year. The geology of this area is mostly sedimentary considered as Cretaceous–Tertiary and Quaternary sediments (Buchanan and Pugh, 1955).

Field Study: The soils were characterized following the procedures outlined in the Soil Survey Staff (1951) and Guidelines for soil profile description (FAO-UN, 1977). Soil profiles could not readily be established due to high groundwater table, less than 10 cm deep at low tide and flooded at high tides. Therefore the soils' morphological descriptions were carried out using the core samples obtained through the use of Dutch soil auger. Thereafter, bulk samples of the soil from each genetic horizon were collected from under *R. racemosa* and *A. germinans* within the study area. Subsamples were analyzed for various physical and chemical properties following the standardized methods described by Tam and Wong (1993, 1995). To assess the capacity of the soils to retain heavy metals, soil leaching experiments were set up as described by Tam and Wong (1995). Polyvinyl chloride columns (10 cm in length by 10 cm in diameter) were packed uniformly with air-dried surface soil. A complete randomized block design of three replicates was used and a total of 12 columns was set up for the two types of mangrove soils. Each column was then leached with either artificial seawater or synthetic heavy metal solution. The synthetic heavy metal solution had the following composition: 20, 50, 20 and 100 mgl^{-1} of Cu, Zn, Cd and Mn respectively with the pH adjusted to 7.1 ± 0.5 because the *in situ* pH of the soils varies from 7.0 to 7.2. The choice of the concentrations of the test metals was based on the analysis of a sample of formation water from one of the existing facilities in Niger Delta (Table 1).

The concentrations of the synthetic metal solutions used closely approximated the average metal concentrations in the aqueous effluent analyzed and reported in Table 1. A quantity of 200 ml freshly prepared synthetic heavy metal solution was applied to each treated column three times a week for 120 days. For the control columns, artificial seawater prepared by dissolving commercial oceanic salt in deionized water was added. At the end of the leaching experiment, the soil masses in each column were collected and divided into two layers according to depth viz: 0-5, and 5-10 cm. Samples from each layer were analyzed for total metal contents by digestion in a 1:1 mixture of conc. HNO_3 and H_2SO_4 following the procedure adopted by Tam and Wong (1996). The Cu, Zn, Cd and Mn concentrations in the digest were determined by atomic absorption spectrophotometry (AAS) and the metal concentrations were presented on dry weight basis. The chemical fractionation of the heavy metals accumulated in the first soil layer (0-5 cm) was analyzed by sequential extraction procedures (Rudd et al., 1988; Wieder et al., 1990). Five-gramme air-dried soil samples were placed in 50-ml centrifuge tubes and subjected to a six-step serial extraction procedures: 20 ml

Table 1: Average properties of a typical aqueous effluent from one of the production facilities in Niger Delta, Nigeria

pH	6.3 ± 0.7
Dissolved oxygen (DO) (mg/liter)	6.8 ± 0.3
COD (mg/liter)	19.9 ± 1.3
Oil and grease (mg/liter)	8.8 ± 0.6
Salinity (Cl^-) (mg/liter)	17.4 ± 0.4
Conductivity (μScm^{-1})	77.9 ± 2.1
Nitrate (NO_3) (mg/liter)	0.31 ± 0.03
Zinc (Zn^{2+}) (mg/liter)	52.0 ± 0.3
Copper (Cu^{2+}) (mg/liter)	20.7 ± 0.02
Chromium (Cr^{6+}) (mg/liter)	13.0 ± 0.4
Cadmium (Cd^{2+}) (mg/liter)	19. ± 0.3

Source: SPDC-W (1996). Report of aqueous effluent monitoring for Batan and Odidi Fields.

deionized water for 30 min.; 25 ml 1 M KNO_3 overnight; 25 ml 0.5 M KF overnight; 25 ml 0.1 M $Na_4P_2O_7$ overnight; 25 ml 0.3 M $Na_3C_6H_5O_7$, 2.5 ml 1 M $NaHCO_3$ and 0.5g $Na_2S_2O_4$ for 30 min. at 80^{o}C and 25 ml 6 M HNO_3 overnight. Between each extraction, the soil residues were washed with deionized water to remove the unused reagent. The six fractions obtained were referred to as water-soluble, exchangeable, inorganically bound, organically bound, Fe and Mn oxide bound and residual (sulphide and precipitated) respectively following the method of Tam and Wong (1996).

RESULTS AND DISCUSSION

Morphological Properties of the Soils: The soils in the mangrove ecosystem of the Niger Delta, Nigeria are located within the intertidal zone of the region. The soils are inundated (submerged) by salt water at every high tide though a few areas are only inundated by spring tides but not neap tides (Anderson, 1967). Table 2 gives the morphological properties of the soils.

The soils are characterized by the presence of thin (0-3 cm) to moderately thick (10-15 cm) layer of alluvium (mud) on top of the root-mat (the histic, O*i*, epipedon). The alluvium is very fine-textured and is considered to be recently deposited following the flocculation of the silt and clay suspended in the water brought down by the Niger river (Anderson, 1967). Typically, the surface mud varies in colour from very dark grayish brown (10YR 3/2) to very dark grayish brown (2.5Y 3/2) but generally without mottling possibly due to periodic inundation by tidal water. The surface mud is clayey in texture, massive in structure and very sticky wet (Table 2). Bubbles arise when the mud is disturbed and H_2S can be smelt in the gas. The fibric soil material underlying the surface mud varies in thickness from about 70 cm to almost 100 cm. This fibric soil material was recognized as peat by Anderson (1967) and sapric (Coultas and Calhoun, 1976). However from this study, the fibric soil material is not highly decomposed but instead shows as slightly decomposed organic material with the fiber content being more than 40% (by volume) after rubbing. The level of its decomposition and fiber content qualify it as O*i* genetic horizon (Soil Survey Staff, 1998). Beneath the root-mat, i.e. the histic layer, is the plastic, very sticky, massive clay.

***The Physical and Chemical Properties of the Soils*:** Table 3 shows the physical properties of the soils. The soils are dominated by fine particles of silt (23-44%) and clay (46-76%).

The surface mud is thicker and slightly more clayey in soils under the *R. racemosa* (red mangrove) than those under *A. germinans* (white mangrove). Table 4 presents the chemical properties of the soils. The soils were near neutral (pH 7.0 - 7.2) in reaction under field conditions but became more acid (pH 3.3 – 4.8) upon drying indicating the oxidation of S compounds (Coul-tas and Calhoun, 1976). Electrical conductivity values indicated that all of the mangrove soils were highly saline. Conductivity varies from 10.5 – 11.3 mmhos/cm in soils under *A. germinans* to 15.4 -15.8 mmhos/cm under *R. racemosa*. The level of soluble salts was very high ranging from 22, 891.6 to 23,160.07 µg/g in soils under the *R. racemosa*, and 18,830.20 – 20, 660.10 µg/g under *A. germinans*. Equally high in the soils is the

Table 2: Morphological characteristics of soils in the mangrove forest of the Niger Delta, Nigeria

Horizon	*Depth (cm)*	*Moist dominant colour*	*Field* texture*	*Structure†*	*Consistence‡*	*Lower boundary§*
Soils under *R. racemosa*						
C	0-5	10YR 3/2	C	m	wvs	cs
O*i*	5-85	10YR 2/2	fibrous	m	mfr	cs
IIC	85-120	2.5Y 5/4	C	m	wvs	cs
Soils under *Avicennia germinans*						
C	0-3	2.5Y 3/2	C	m	mvs	cs
O*i*	3-75	2.5Y 4/2	fibrous	m	mfr	cs
IIC	75-120	2.5Y 5/2	C	m	wvs	cs

* C – clay,
† m – massive,
‡ wvs – wet very sticky; mfr – moist friable
§ cs – clear smooth

Table 3: Physical properties of the mangrove soils in the Niger Delta, Nigeria

Horizon	*Depth (cm)*	*Sand (mm)*						*Silt*	*Clay*	*Textural*
		VCS (1-2)	*CS (0.5-1.0)*	*MS (0.25-0.5)*	*FS (O.1-0.25)*	*VFS (0.1-0.05)*	*TS (0.05-2)*	*(2-50μm)*	*(<2 μm)*	*class*
					%					
Soils under *Rhizophora racemosa*										
C	0-5	0.0	0.0	0.0	0.0	1.0	1.0	23	76	Clay
O*i*	5-85	-	-	-	-	-	-	-	-	Fibrou
IIC	85-120	0.0	0.0	2.0	2.0	6.0	10.0	44	46	Silty clay
Soils under *Avicennia germinans*										
C	0-3	0.0	0.0	1.0	2.0	12.0	15.0	33	52	Clay
O*i*	3.75	-	-	-	-	-	-	-	-	Fibrous
IIC	75-120	0.0	0.0	0.0	0.0	10.0	10.0	42	48	Silty clay

VCS – very coarse sand, CS – coarse sand, MS-medium sand, FS-fine sand, VFS – very fine sand, TS – total sand.

Table 4: Chemical properties of the mangrove soils in the Niger Delta, Nigeria

Horizon	*Depth (cm)*	*pH in field moist*	*H_2O air dry*	*Conductivity (mmhos/cm)*	*Redox potential (mV)*	*ESP (%)*	*Soluble salts (μg/g)*	*ECEC (cmol(+)kg^{-1})*	*Total N (%)*	*TOC (%)*	*PO_4^{3-} – P (μg/g)*
Soils under *Rhizophora racemosa*											
C	0-5	7.2	4.4	15.6	-117	25.80	23,160.07	13.25	3.11	6.86	41.22
Oi	5-85	7.2	4.3	15. 4	-120	24.10	22,891.6	3.60	0.14	14.12	10.24
IIC	85-120	7.1	3.5	15.8	- 123	25.60	23,082	12.12	0.58	3.83	7.92
Soils under *Avicennia germinans*											
C	0-3	7.0	4.8	11.3	-84	22.92	20,660.10	10.15	1.34	2.42	21.5
Oi	3-75	7.0	3.3	10.5	-96	20.33	18,970.70	3.13	0.16	9.6	23.63
IIC	75-120	7.0	3.7	11.1	-109	22.34	18,830.20	10.63	0.43	1.79	12.62

exchangeable sodium percentage (ESP) with values varying from 20.33 to 25.8% in the soils. The high values of ESP and soluble salts possibly accounted for the predominance of *R. racemosa* and *A. germinans* and almost complete absence of commonly cultivated arable and tree crops. The other plants observed on the field within the mangrove forest were mainly *Paspalum* sp. (a grass) and *Acrostichum aureum* (a fern). The effective cation exchange capacity (ECEC) of the soils ranged from as low as 3.13 to 3.60 cmol(+) kg^{-1} in the fibric soil material layer to 10.15 – 13.25 cmol (+) kg^{-1} in the surface mud and 10.63 to 12.12 cmol(+)kg^{-1} in the subsoil mineral layer Table(4). Much higher values were reported in Florida by Coultas and Calhoun (1976) but attributed the high values to the limestone underlying the soils. In this study, the subsoil mineral layer is underlain by the alluvium deposited by the Niger river. The O*i* layers have the highest C/N ratios. The O*i* layer in soils under the *R. racemosa* had C/N ratio of about 100.86 compared to 60 in similar layer under *A. germinans*. The comparatively lower C/N ratios of 2.21 in the surface mud under *R. racemosa* and 1.81 under *A. germinans* are a reflection of greater microbial activity of the surface horizons and denitrification in the more permanently anaerobic subsurface horizons. The values of the redox potential (-84 to – 123 mV) measured in the field showed that the soils were highly reduced.

Generally the soils have no mineral horizons within the top 100 cm or more of the fibrist soil material and are saturated with water for much more than 30 days in a year. These characteristics of the soils meet the requirement for Histosols (Soil Survey Staff, 1998). The fibre content of the soils is more than 40 cm thick and the fibric sphagnum constitutes more than three – fourths by volume to depth greater than 90 cm from the surface. Thus the soils belong to Fibrists Suborder and Sphagnofibrist Great Group. At the subgroup level, the soils are placed as Typic Sphagnofibrists. Similar soils in the region were classified as Typic Sulfaquent (Akpan-Idiok and Esu, 2001).

Retention and Distribution of Total Heavy Metals in the Mangrove Soils: Significantly higher concentrations of total Cu, Zn, Cd and Mn were found in both types of mangrove soils receiving the metal solutions compared to the control (Table 5). This indicates that mangrove soils can retain heavy metals. The ability of mangrove soils to sequester metals was reported to be positively related to the content of clay, organic matter and reduced condition. Tidal marsh sediments with high contents of clay and organic matter and more negative redox potential sequestered more heavy metals (Tam and Wong, 1996). In this study, soils under *R. racemosa* had higher clay, TOC and were more reduced (–117 mV) compared to those under the *A. germinans* (-84 mV). These factors possibly accounted for the ability of soils under *R. race-mosa* to retain more heavy metals than those under *A. germinans*. Most of the added heavy metals accumulated in the surface 0-5 cm layer (Table 5) with enrichment factors (EF) for Cu, Zn, Cd and Mn being higher than 1. The high value of the EF is an indication of the high potential of the soils to retain heavy metals. The metal concentrations in the 5-10 cm soil depth were significantly lower than in the surface 0-5 cm. This suggested that anthropogenic heavy metals were mainly localized in the top few centimeters, and moved downwards only when the retention capacity of the surface soil mass became saturated. Similar findings were reported by previous workers (Banus et al., 1993; Tam and Wong, 1993).

Chemical Fractionation of Heavy Metals Retained: In this study, chemical fractionations of Cu, Zn, Cd and Mn in soils receiving synthetic heavy metal solutions were significantly different from that of the control for both soil types. The water-soluble fraction (i.e. deionised water extractable form) of the heavy metals ranged 0, 2.0, 2.5 to 5% for Cu, Zn, Mn and Cd respectively (Table 6) for soils under *R. racemosa*. Under *A. germinans*, the extractable heavy metals ranged from 0% for Cu and Cd to 3 and 5% for Zn and Mn respectively.

This trend shows that very little of the sequestered metals can be re-mobilized by mere shaking in water. Similarly, low concentrations of exchangeable (the KNO_3 soluble) and inorganically bound (KF soluble) fractions were obtained. However, in the treated soils, most of the heavy metals retained were organically bound ($Na_4P_2O_7$ extractable). For instance in this study, as much as 65 -71% Cu, 65.2 - 68.0% Zn, 59.4 - 63.0% Cd and 40.7 - 42.4% Mn were organi-cally bound. Thus, the adsorption of Cu, Zn and Cd onto organic materials was found to be an important process in the mangrove soils. Young *et al*. (1992) and Chakrapani and Subramanian (1993) similarly reported strong adsorption of Cu and Cd to organic materials. In the control, the organically bound and residual appeared as the major adsorption sites for Cu, Cd and Zn whereas the organically and Fe and Mn oxide bound fractions were more significant for Mn. Next in order of importance as the adsorption site is the inorganically bound fraction, possibly due to high content of clay. From this study, as much as 12.3-14.0% Cu, 9.8-11.3% Zn and 13.2-14.2% Cd were inorganically bound. This implies that the amounts of organic matter, clay and Fe & Mn oxides in the soils play an important role in determining the ability of the mangrove soils to retain heavy metals. These results suggested that anthropogenic heavy metals were weakly adsorbed probably due to the negatively charged sites of organics and clay. These loosely bound metals may be desorbed to re-enter the aqueous phase by complex equilibrium reactions or by mass action of more abundant cations. This means that, at least, some of the retained metals may become secondary sources of metal pollution.

***Socio-economic Implication of the Study to Man and the Environment*:** The accumulation of heavy metals, e.g. Cu, Zn, Pb, Cr, etc, in soils is of concern in agriculture due to the potential threat of adversely affecting food quality (safety and marketability), crop growth (through phyto-toxicity) or environmental health (soil flora/fauna and terrestrial animals including man). Metal impurities enter the food chain through accession from the atmosphere, through fertilizer use and because agricultural land is increasingly seen in

Table 5: Total metal retained (mg/kg) by the soils under different vegetations

Heavy metals	*Soil under different vegetations*	*Soil column and Enrichment factor (EF)*			
		0-5 cm	*EF*	*5-10cm*	*EF*
Cu					
	R. racemosa	280.7	20.4	170.5	11.9
	A.germinans	130.4	8.9	60.4	3.6
	Control	13.1	-	13.20	-
Zn	*R. racemosa*	1200.3	16.5	130.6	0.9
	A.germinans	1000.6	13.6	120.2	0.8
	Control	68.5	-	66.9	-
Cd	*R. racemosa*	28.7	11.3	5.6	1.4
	A.germinans	28.0	11.0	5.2	1.3
	Control	2.34	-	2.3	-
Mn	*R. racemosa*	1346.1	1.2	1200.6	1.1
	A.germinans	1206.0	1.0	1100.7	0.9
	Control	600.7	-	580.0	-

Table 6: Percentage sequential extraction of heavy metals in the mangrove soil

Extracting solution	*Soils under R.racemosa*		*Soils under A. germinans*	
	Control	*Treated*	*Control*	*Treated*
Deionised H_2O	0	0	0	0
1 M KNO_3	6.1	4.6	4.0	15.9
0.5 M KF	1.5	12.3	7.6	14.0
Cu 0.1 M $Na_4P_2O_7$	41.0	71.0	36.3	65.0
0.3 M $Na_3C_6H_5$+1M $NaHCO_3$ + 0.5 $_g$ $Na_2S_2O_4$	9.6	3.6	1.3	2.3
6 M – HNO	41.7	8.4	50.7	2.8
Deionised H_2O	-	2.0	-	3.0
1 M KNO_3	-	4.1	-	6.8
0.5 M KF Zn	19.7	11.3	21.8	9.8
0.1 M $Na_4P_2O_7$	30.5	65.2	30.2	68.0
0.3 M $Na_3C_6H_5$+1 M $NaHCO_3$+ 0.5 $_g$ $Na_2S_2O_4$	11.3	7.3	13.4	8.2
6M – HNO_3	38.4	10.0	34.6	4.1
Deionised H_2O	-	5.0	-	-
1 M KNO_3	-	3.0	-	6.7
0.5 M KFCd	30.2	14.2	30.0	13.2
0.1 M $Na_4P_2O_7$	18.7	63.0	16.4	59.4
0.3 M $Na_3C_6H_5$+1 M $NaHCO_3$ + 0.5 $_g$ $Na_2S_2O_4$	31.6	10.8	31.8	14.4
6 M HNO_3	19.4	4.0	21.7	6.2
Deionised H_2O	0.5	2.5	1.0	1.5
1 M KNO_3	10.3	16.0	12.0	13.8
0.5 M KFMn	15.0	25.0	14.0	23.4
0.1 M $Na_4P_2O_7$	33.6	40.7	38.2	42.4
0.3 M $Na_3C_6H_5$+1 M $NaHCO_3$+ 0.5 $_g$ $Na_2S_2O_4$	32.1	13.6	31.5	12.1
6 M HNO_3	8.4	2.2	3.3	6.8

The mean percentages of each fraction to the sum total of metal concentrations from three replicates are presented.

many countries as a suitable receptor for wastewater, biosolids and green wastes from urban areas (McLaughlin et al., 2000). A unique source of metals into wetland soils in Nigeria Niger Delta is through the release of industrial wastewater from flow-stations operated by the petroleum prospecting and producing companies into creeks and rivers within the inter-tidal mangrove swamp areas. The guidelines and regulatory framework for monitoring the level of impact in the environment (DPR, 2002) was restricted to water-bodies, yet at high tides, the wastewater when mixed with the tidal flow can readily impact the soil resources in the region including the infauna, epifauna, and the flora supported by such soils. Bioaccumulation of metals by fauna and flora and sometimes loss of biodiversity can readily occur, hence the need to re-examine the nations' regulatory monitoring guideline in view of the findings from this study.

CONCLUSION

The present study shows that the soils under the mangrove (*R. racemosa* and *A. germinans*) forest in the Niger Delta, Nigeria, are inundated by tidal flow and are characterized by the presence of very fine textured, thin (0-3 cm) to moderately thick (10-15 cm) layer of alluvium on top of the root mat (the histic , O*i*, epipedon). The fibric soil material beneath the surface mud varies in thickness from about 70 to 100 cm, and beyond the histic layer is the plastic, very sticky, massive clay. *In situ*, the soils are near neutral (pH 7.0 - 7.2) in reaction but became strongly acid (pH 3.3 – 4.8) upon drying. They are saline, high in soluble salts, highly reduced, with low CEC in the fibric layer but high in the mineral, clayey subsoil horizon. The soils are saturated with water for much more than 30 days in a year and have fibre content of more than 40 cm thick with the fibric sphagnum constituting more than three – fourths by volume to depth greater than 90 cm. The soils are therefore classified as Typic Sphagnofibrists, and it was observed that the soils sequestered considerable amounts of Cu, Zn, Cd, and Mn with most of the metals retained in the surface 0-5 cm soils. The anthropogenic heavy metals were adsorbed probably to the negatively charged sites of organics and clay. These loosely-bound metals may re-enter the aqueous phase through desorption, thus becoming secondary sources of metal pollution in the environment. This is of concern in agriculture due to the potential threat of adversely affecting food quality (safety and marketability), crop growth (through phytotoxicity) or environmental health (soil flora/fauna and terrestrial animals including man).

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