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MICROBIOLOGICAL AND PHYSICO-CHEMICAL STUDIES OF INLAND WETLAND SOILS IN IKOT EKPENE, NIGERIA

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The microbiological and physicochemical characteristics of wetland soils in Ikot Ekpene Local Government Area were studied between May 2001 and June 2003. Total heterotrophic bacterial count (THBC); total fungal counts(TFC) and total actinomycetes counts (TAC) were determined from soil samples taken at 0-15 and 15-30 cm depths from Nyara Enyin, Ikot Oto, Ikot Ubo and Ikot Osurua in the wet and dry seasons. Microbial isolates were characterized and identified. Physicochemical parameters (particle size, pH, EC, organic matter, %N, available phosphorus, exchangeable acids, ECEC, % base saturation and micro-nutrients) were determined using standard methods. The THBC of wetland soils in Ikot Ekpene ranged from 4.6 (±0.11) x 10^6 to 1.8 (±0.01) x 10^7 cfu g^{-1} in the wet season and from 2.6 (±0.111) x 10^6 to 1.4 (±0.22) x 10^7 cfu g^{-1} in the dry season, while TFC ranged from 1.8 (±0.0^7) x 10^6 to 6.8 (±0.04) x 10^6 cfu g^{-1} in the wet season and from 1.0 (±0.01) x 10^6 to 4.6 (±0.21) x 10^6 cfu g^{-1} in the dry season. The TAC ranged between 1.2 (±0.22) x 10^6 to 6.0 (±0.01) x 10^6 cfu g^{-1} in the wet season and ranged between 1.0 (±0.02) x 10^6 and 2.6 (±0.17) x 10^6 dug^{-1} in the dry season. The bacteria isolated included the genera *Acinetobacter, Arthrobacter, Bacillus, Clostridium, Enterobacter, Micrococcus, Serratia, Staphylococcus, Enterococcus, and Pseudomonas.* The fungal isolates were of the genera *Aspergillus, Fusarium, Penicilium and Mucor.* Actinomycetes isolated were of the genera *Streptomyces* and *Norcadia.* Physicochemical analyses showed the soil type as varying from sandy to sandy clay loam and acidic. The results of chemical analyses showed that the wetland soils can support sustainable agricultural activities; the vast expanse of wetland soils in Nigeria which hitherto were regarded as wastelands can be productively exploited.

Key Words: Inland wetland soils, Microbiological and physico-chemical characteristics, Sustainable agriculture

INTRODUCTION

Wetlands comprise soils with impeded drainage, either because of flooding or because of a relatively high ground water table (Andriesse, 1986). They have been recognized as peatbogs, swamps, tidal marshes, floodplains consisting of recent alluvial deposits bordering rivers, inland valleys, shallow ponds, mudflats and littoral areas of larger bodies of water (Gopal *et al,* 1982). The wetlands in the world are estimated at about 4-6% of the earth's land surface (Mitsch, 1997). In Nigeria, wetlands cover over 24,009km^2, with the largest concentration of natural wetlands being found in the Niger Delta region of southern Nigeria (Eshiett, 1992).

Akwa Ibom State lies entirely on the coastal plain soils of South Eastern Nigeria (Peters, 1989). Currently, wetland soils in Akwa Ibom State provide areas where economic activities such as gravel and fine sand extraction and lumbering are carried out but little or no crop production are practised (Eshiett, 1994).

There is a paucity of information on the microbiological and physicochemical characteristics of the wetland soils in Ikot

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Ekpene LGA, Nigeria. The aim of this study hich the potentials and management of these wetland soils can be achieved.

MATERIALS AND METHODS

Study Area

The inland wetland soils in Ikot Ekpene are located along the Udo Nwankwo River Basin (the section of Qua Iboe River that passes thro igh Ikot Ekpene by the Akwa Ibom State Polytechnic) (Fig. 1.0). The topography of the study area can be described as being nearly level to gently undulating slopes of 0-3°, which provides a very stable physiographic environment for relatively uniform parent materials. Apart from the Polytechnic, the Major Seminary in Akwa Ibom State is also located on this slop.

COLLECTION OF SAMPLES

Soil samples from this study area were collected at two depths (0-15cm and 15- 30cm) from four locations: Nyara Enyin, Ikot Oto, Ikot Ubo and Ikot Osurua (Table 1.0) to represent the upper, middle, lower and bottom slopes along a transect according to the method of Anderson and Ingram (1993). The samples were collected during the wet (April - October) and dry (November - March) seasons. Samples were taken into labelled polythene bags and transported immediately in ice-packed coolers to the laboratory for microbiological and physicochemical analyses.

MICROBIOLOGICAL ANALYSIS

(i) Serial Dilution

Serial ten-fold dilutions of the soil samples were made out according to the methods of Collins and Lyne (1976) and Harrigan and/ McCance (1976).

(ii) Inoculation and Incubation

One milliliter of appropriate ten-fold serial dilutions of the soil samples were inoculated onto nutrient agar (Oxoid CM 314), reinforced clostridial agar (Oxoid, CM 149, 151), malt extract agar (Oxoid CM 151) and Sabouraud dextrose agar plates in triplicates using the pour plate methods of Collins and Lyne (1976) and Harrigan and McCance (1976) and the spread plate methods of Demain and Davies (1999). The soil plate techniques of Eka and Fogathy (1972) and Demain and Davies (1999) were also used for the isolation of actinomycetes using starch nitrate agar. Inoculated plates were incubated at 37°C for 18-24 hrs and at ambient temperature (28±2°C) for 48- 72 hrs for the enumeration of total heterotrophic bacterial, fungal and actinomycetes counts. Visible discrete colonies in incubated plates were counted and expressed as colony forming units per gram (cfu/g) of soil samples.

(iii) Maintenance of Pure Culture

Discrete colonies were purified by repeated sub-culture unto appropriate nutrient media. Pure cultures were preserved on nutrient agar slants and stored in the refrigerator (4°C±2°C) and at ambient temperature (28°C±2°C) for further tests.

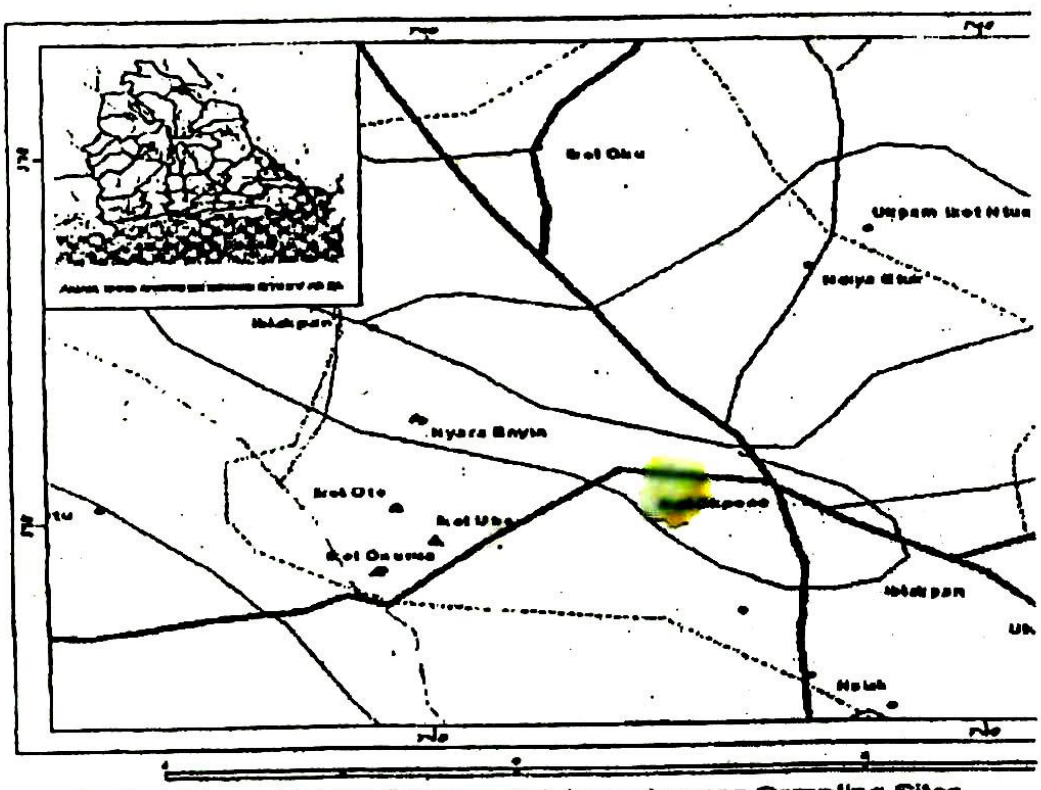

Fig 1 Ikot Ekpene Local Government Area showing Sampling Sites

Table 1: Sampling Points and their coordinates

S/No	Sampling Point	Sample Location (Code)	Coordinates	
			Latitude	Longitude
1				0"
2	Middle Slope	Ikot Oto (KTK)	7° 40' 57"	5° 10' 24"
3	Lower Slope	Ikot Ubo (KTU)	7° 40' 35"	5° 09' 56"
4	Bottom Slope	Ikot Osurua (KTS)	7° 40' 14"	5° 09' 22"

(iv) **Characterization and Identification of Microbial Isolates**

Pure cultures of microbial isolates were characterized based on cultural parameters, microscopic techniques and biochemical tests including carbohydrate utilization as described by Cruickshank *et al* (1975). Identification of the bacterial isolates was accomplished by comparing the characteristics of the cultures with those of known taxa using Bergey's Manual of Determinative Bacteriology (Holt *et al.*, 1994). Characterization and identification of fungi was done according to Domsch *et al* (1980) and Barnet and Hunter (1987). Actinomycetes were characterized and identified according to the methods of Eka and Fogathy (1972).

PHYSICOCHEMICAL ANALYSIS OF SOIL SAMPLES

Particle size analyses of the soil samples were done using the Bouyoucous Hydrometer method (Bouyoucous, 1962). The pH was determined according to the method of Udo and Ogunwale (1986), while electrical conductivity of the soil samples was determined according to Jackson (1962). Exchangeable cations were determined according to the methods of Jackson (1962) and AOAC (1990). Total nitrogen in the soil sample was determined by Microkjedahl digestion and distillation methods of Jackson (1962). Available phosphorus was determined by the Bray No.1 method (Bray and Kurtz, 1945) and blue molybdocolorimetric method (Murphy & Reiley, 1962). Effective cation exchange capacity (ECEC) was determined according to Peters (1989). Total organic matter (TOM) contents of soil sample were determined using the method of Walkley and Black (1934) while micro nutrients (heavy metals) of the soil samples were determined using the atomic absorption spectrophotometer (UNICAM, AA 919 model) (AOAC, 1990).

STATISTICAL ANALYSIS

The statistical analyses employed in this work included standard deviation, analysis of variance and correlation analysis (Sokal and Rohlf, 1981).

RESULTS

MICROBIOLOGICAL PROFILES

(a) **Microbial Counts**

The total heterotrophic bacterial counts (THBC), total fungal count (TFC and actinomycete counts (TAC) obtained from the surface (0-15cm) and subsurface (15-30cm) soil samples at the various locations during the wet and dry seasons are as shown in Table 2. THBC ranged from 4.6 ($\pm$0.11) X 10^6 to 1.8 ($\pm$0.01) X 10^7 cfu/g and 2.6 ($\pm$0.11) X 10^6 to 1.4 ($\pm$0.22) X 10^7 cfu/g in the wet and dry seasons, respectively. TFC ranged from 1.8 ($\pm$0.07) X 10^6 to 6.8 ($\pm$0.01) X 10^6 cfu/g and 1.0 ($\pm$0.01) X 10^6 to 4.6 ($\pm$0.21) X 10^6 cfu/g in the wet and dry seasons respectively. TAC ranged between 1.2 ($\pm$0. 22) X 10^6 and 6.0 ($\pm$0.01) X 10^6 cfu/g in the wet season and ranged between 1.0 ($\pm$0.02) X 10^6 and 2.6 ($\pm$0.17) X 10^6 cfu/g in the dry season. THBC were highest in the surface (0-15cm) soil samples than the sub-surface (15 - 30cm) soil samples at all the locations while T AC were lower than THBC and TFC at all locations sampled.

(b) **Microbial Isolates from Inland Wetland Soils**

The bacterial isolates from Ikot Ekpene wetland soils belonged to the genera *Acinetobacter, Arthrobacter, Bacillus, Clostridium, Enterobacter, Micrococcus, Serratia, Staphylococcus, Enterococcus and Pseudomonas.* Fungal isolates of the wetland soils were members of the genera *Aspergillus, Fusarium, Penicillium and Mucor* while actinomycetes isolated belonged to the genera *Streptomyces and Norcadia.*

PHYSICOCHEMICAL ANALYSES

(a) Particle Size Distribution

The physical characteristic of the inland wetland soils showed it to be dominated by high sand fraction in both seasons (Table 3.). The percentage sand fraction ranged from 68.8 (±0.2) to 90.8 (±0.2) % in the wet season and 70.4 (±0.06) to 91.8 (±0.04) % in the dry season. Silt was the least, ranging from 2.4 (±0.02)% to 12.4 (±0.01)% at all locations in the two seasons. The silt components were generally found to be higher in the subsurface soils than surface soils.

(b) The Chemical Analysis of Wetland Soil

The chemical analysis of the wetland soils in both seasons is as presented in Tables 4a and b. The pH ranged between 5.4 (±0.01) and 5.8 (±0.01), organic matter, 1.61 (±0.17) to 4.93 (±0.01)%; nitrogen, 0.04 (±0.02) to 0.14 (±0.02)%; available phosphorus; 23.72 (±0.07) to 50.31 (±0.4) mg/kg.

(c) Micronutrient of Wetland Soils

The analysis for the micronutrient content of the wetland soils is as presented in Table 5. Iron had the highest concentration with a range from 32.1 (±0.00) to 39.5 (±0.00) mg/kg and copper was least, with a range from 0.9 (±0.03) to 1.7 (±0.01) mg/kg in both seasons.

DISCUSSION

This work on the microbiological and physicochemical studies of Inland wetland soils in Ikot Ekpene, was designed to document the microbiological and physicochemical characteristics with a view to providing some baseline data for effective management for sustainable agricultural development. Population increase, and increased industrialization and urbanization have put so much pressure on existing agricultural lands leading to declining productivity from upland agricultural practices due to continuous cultivation. There is the compelling need therefore to explore the possibility of utilizing the hitherto vast and unexploited wetlands for sustainable agricultural production to address the food security problems in Nigeria.

The activities of soil microorganisms influence the physical, chemical and mineralogical properties of soils (Atlas and Bartha, 1998). Studies by a number of workers have shown that the characteristic of a wetland vary widely in accordance with the multiplicity and diversity of ecologies with which the wetlands are associated (Eshiett, 1992; Kamalu and Isirimah, 1992; Eshiett, 1994).

The microbial counts of wetland soils of Ikot Ekpene Local Government area, compared favourably with microbial counts of wetland soils of Eket (Udotong and Akpanekon, 2006a) and Itu (Udotong and Akpanekon, 2006b) in particular and the Niger Delta region (RPI, 1985), in general. A decrease in microbial counts with increase in soil depth obtained in both seasons during this study is normal and could be attributed to the greater availability of oxygen and other favourable growth factors such as soil organic matter, etc., at the surface soil than at the sub-surface soil levels (Brady, 1984; Alexander, 1985). The slight variations in the microbial counts of both seasons could be attributed to factors such as climatic changes, which in turn bring about changes in the wetland soil properties.

The microbiological study of the inland wetland soils has shown that the soils of Ikot Ekpene play host to various genera of bacteria, fungi and actinomycetes which play critical roles in biogeochemical cycling and hence soil fertility (Brady, 1984; Alexander, 1985; Atlas and Bartha, 1998). Species of the genera *Arthrobacter, Bacillus, Clostridium and Pseudomonas* are known to be actively involved in biogeochemical cycling of some minerals (Alexander, 1985; Atlas and Bartha, 1998). These microbial isolates from the inland wetland soils under study compare favourably with isolates obtained from wetland soils of Eket, Itu and the Niger Delta region (Udotong and Akpanekon, 2006a,b; RPI, 1985). These organisms have also been isolated from normal agricultural soils within the Niger Delta region

TABLE 2: MICROBIAL COUNT OF ISOLATES FROM IKOT EKPENE WETLAND SOIL

Sample Code	Depth (cm)	(THBC) ($X10^6$, 10^7 cfu/g)		(TAC) ($X10^6$ cfu/g)		(TFC) ($X10^4$ cfu/g)	
		Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season
KTN	0 – 15	$1.06\pm0.22X10^7$	$7.8\pm0.08x10^6$	3.4±0.53	2.2±0.11	4.8±0.01	1.6±0.38
KTN	15 – 30	$4.6\pm0.11x10^6$	$2.6\pm0.11x10^6$	1.4±0.53	1.2±0.01	2.0±0.12	1.0±0.01
KTK	0 – 15	$1.4\pm0.04x10^7$	$1.0\pm0.17x10^7$	4.2±0.44	2.0±0.12	5.0±0.01	2.6±0.24
KTK	15 – 30	$6.2\pm0.03x10^6$	$4.2\pm0.32x10^6$	1.8±0.44	1.2±0.13	2.8±0.05	1.4±0.11
KTU	0 – 15	$1.6\pm0.01x10^7$	$1.2\pm0.15x10^7$	6.0±0.01	2.6±0.17	6.8±0.04	3.8±0.08
KTU	15 – 30	$9.4\pm0.07x10^6$	$5.2\pm0.03x10^6$	2.2±0.11	1.6±0.11	3.6±0.01	2.0±0.23
KTS	0 – 15	$1.8\pm0.01x10^7$	$1.4\pm0..22x10^7$	3.0±0.44	1.8±0.15	4.6±0.19	4.6±0.21
KTS	15 – 30	$9.4\pm0.00x10^6$	$6.8\pm0.11x10^6$	1.2±0.22	1.0±0.02	1.8±0.07	2.6±0.16

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TN = Nyara Enyin; KTK = Ikot Oto; KTU = Ikot Ubo; KTS = Ikot Osurua; THBC = total Heterotrophic Bacterial Count; TFC = Total Fungal Count; TAC = Total Actinomycetes Count.

TABLE 3: PARTICLE SIZE DISTRIBUTION OF IKOT EKPENE WETLAND SOIL

Sample Code	Depth (Cm)	Sand (%)		Clay (%)		Silt (%)	
		Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season
KTN	0 – 15	90.8±0.2	91.8±0.04	6.8±0.02	5.8±0.02	2.4±0.02	2.6±0.0
KTN	15 – 30	86.8±0.2	86.0±0.01	10.8±0.02	9.6±0.01	2.4±0.02	4.6±0.01
KTK	0 – 15	84.4±0.05	84.4±0.03	11.4±0.02	10.2±0.04	4.2±0.01	5.4±0.02
KTK	15 - 30	72.4±0.12	72.4±0.05	16.4±0.07	16.0±0.03	11.2±0.02	11.6±0.12
KTU	0 – 15	78.4±0.02	78.0±0.01	11.4±0.01	11.2±0.2	10.2±0.01	10.8±0.2
KTU	15 - 30	70.4±0.01	70.4±0.06	19.4±0.03	18.0±0.02	10.2±0.05	11.6±0.02
KTS	0 – 15	72.8±0.01	73.8±0.02	14.8±0.01	14.6±0.01	12.4±0.01	11.6±0.04
KTS	15 - 30	68.8±0.02	70.8±0.04	20.8±0.05	18.6±0.04	10.4±0.00	10.6±0.08

KTN = Nyara Enyin; KTK = Ikot Oto; KTU = Ikot Ubo; KTS = Ikot Osurua;

Each value is ±

TABLE 4A: CHEMICAL ANALYSIS OF IKOT EKPENE WETLAND SOIL (WET SEASON)

Sample Code	Depth (cm)	pH	EC (ds/m)	Organic Matter (%)	N (%)	Av. P (Mg/kg)	Ca (Cmol./kg)	mg	Na	K	EA	ECEC	B. S (%)
KTN	0-15	5.5±0.02	0.03±0.00	2.30±0.00	0.08±0.00	46.0±0.00	2.4±0.00	1.4±0.00	0.07±0.00	0.19±0.00	1.69±0.00	5.75±0.00	69.8±0.00
KTN	15 – 30	5.6±0.03	0.02±0.00	1.79±0.04	0.06±0.02	45.28±0.00	2.2±0.00	1.2±0.00	0.08±0.02	0.08±0.01	2.3±0.00	5.85±0.00	60.68±0.03
KTK	0 – 15	5.7±0.01	0.02±0.00	3.29±0.00	0.12±0.00	46.35±0.00	46.35±0.00	2.0±0.00	0.04±0.01	0.11±0.00	1.66±0.00	8.13±0.00	78.58±0.00
KTK	15 - 30	5.7±0.01	0.02±0.00	2.73±0.00	0.06±0.00	40.76±0.00	3.36±0.00	1.8±0.00	0.04±0.01	0.10±0.00	1.3±0.00	6.6±0.00	80.3±0.00
KTU	0 – 15	5.8±0.02	0.03±0.00	3.51±0.00	0.13±0.00	40.50±0.00	2.4±0.00	1.4±0.00	0.07±0.02	0.19±0.02	1.69±0.00	5.75±0.00	67.8±0.00
KTU	15 -30	5.8±0.01	0.03±0.00	2.81±0.00	0.10±0.02	27.77±0.00	3.6±0.00	1.8±0.00	0.07±0.02	0.19±0.00	1.83±0.00	6.49±0.00	87.21±0.11
KTS	0 – 15	5.6±0.01	0.03±0.00	4.93±0.01	0.14±0.02	57.85±0.01	4.13±0.02	2.1±0.01	0.07±0.20	0.1±0.00	1.69±0.00	8.09±0.00	75.77±0.00
KTS	15 - 30	5.6±0.01	0.02±0.00	2.97±0.00	0.08±0.00	0.08±0.00	1.68±0.07	1.2±0.04	0.05±0.00	0.14±0.00	1.97±0.00	5.04±0.01	60.91±0.00

KTN = Nyara Enyin; KTK = Ikot Oto; KTU = Ikot Ubo; KTS = Ikot Osurua;
N = Nitrogen; Av.P = available phosphorus; Ca = Calcium; Mg = Magnesium; Na = Sodium; K = Potassium; EA = exchangeable acids;
ECEC = Exchangeable cation exchange capacity; B.S = Base saturation.

TABEL4B: CHEMICAL ANALYSIS OF IKOT EKPENE WETLAND SOIL (DRY SEASON)

Sample Code	Depth (cm)	pH	EC (dsim)	Organic Matter (%)	N (%)	Av.P (mg/kg)	Ca (Cmol/kg)	mg	Na	K	EA	ECEC	B. S (%)
KTN	0-15	5.4±0.01	0.05±0.00	1.94±0.00	0.05±0.00	42.5±0.00	2.26±0.00	1.2±0.00	0.07±0.00	0.08±0.06	1.3±0.00	5.85±0.00	60.7±0.03
KTN	15 - 30	5.4±0.01	0.04±0.00	1.61±0.17	0.04±0.02	40.2±0.00	1.96±0.00	1.3±0.00	0.07 ±0.02	0.06±0.09	3.29±0.00	6.68±0.00	50. 8±0.11
KTK	0 - 15	5.5±0.01	0.03±0.00	2.34±0.02	0.06±0.00	42.0±0.00	3.6±0.00	1.80±0.00	0.07 ±0.04	0.19±0.06	0.83±0.00	4.49±0.00	87.2±0.06
KTK	15 - 30	5.5±0.01	0.03±0.00	1.78±0.03	0.04±0.02	40.4±0.00	2.61±0.00	1.31±0.00	0.09±0.01	0.16±0.07	2.2±0.00	6.37±0.00	65.4±0.00
KTU	0 - 15	5.6±0.02	0.03±0.00	2.97±0.03	0.10±0.00	38.1±0.00	2.9±0.00	1.9±0.03	0.06±0.00	0.08±0.02	2.1±0.00	704±0.00	70.2±0.00
KTU	15 -30	5.6±0.00	0.03±0.00	2.36±0.02	0.07±0.00	25.4±0.00	2.2±0.00	1.2±0.00	0.07 ±0.00	0.08±0.00	2.23±0.00	5.85±0.00	60.68±0.0
KTS	0 - 15	5.5±0.01	0.03±0.00	2.23±0.01	0.12±0.02	5031±0.04	3.36±0.04	1.80±0.00	0.06±0.00	0.12±0.00	2.7±0.00	8.04±0.00	66.4±0.00
KTS	15 - 30	5.5±0.01	0.03±0.00	2.67±0.00	0.06±0.00	20.7±0.02	1.7±0.01	11±0.01	0.05±0.02	0.08±0.02	2.7±0.00	5.5±0.08	51.79±0.0

KTN = Nyara Enyin; KTK = Ikot Oto; KTU = Ikot Uboc; KTS = Ikot Osurua;

N = Nitrogen; Av.P = available phosphorus; Ca = Calcium; Mg = Magnesium; Na = Sodium; K = Potassium; EA = exchangeable acids; ECEC = Exchangeable cation exchange capacity; B.S = Base saturation.

TABLE 5: MICRONUTRIENTS OF IKOT EKEPENE WETLAND SOIL (WET AND DRY SEASON)

Sample Code	Depth (Cm)	Copper (Cu) (mg/kg)		Zinc (Zn) (mg/kg)		Iron (Fe) (mg/kg)		Manganese (Mn) (mg/kg)	
		Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry Season
KTN	0 -15	1.01±0.06	0.9±0.03	3.8±0.01	3.6±0.00	39.3±0.00	32.6±0.05	5.1±0.06	5.1±0.07
KTN	15 – 30	1.1±0.01	0.9±0.03	3.8±0.01	3.6±0.00	39.5±0.00	32.1±0.00	5.1±0.06	5.0±0.01
KTK	0 – 15	1.3±0.01	1.0±0.06	3.9±0.01	3.5±0.01	35.1±0.00	32.2±0.01	8.2±0.00	7.1±0.05
KTK	15 - 30	1.3±0.01	1.0±0.01	3.9±0.03	3.5±0.01	35.1±0.00	32.4±0.00	8.2±0.00	7.5±0.05
KTU	0 – 15	1.7±0.01	1.0±0.03	6.7±0.02	4.8±0.11	34.8±0.02	32.4±0.00	10.0±0.00	10.0±0.01
KTU	15 -30	1.7±0.01	1.0±0.02	6.7±0.02	5.0±0.02	35.0±0.00	32.8±0.00	10.0±0.00	10.0±0.02
KTS	0 – 15	1.5±0.01	1.0±0.13	5.1±0.01	4.6±0.00	39.3±0.00	32.4±0.00	10.2±0.00	10.2±0.03
KTS	15 - 30	1.5±0.04	0.9±0.03	5.3±0.01	4.7±0.04	39.3±0.00	33.6±0.01	10.5±0.03	10.4±0.02

KTN = Nyara Enyin; KTK = Ikot Oto; KTU = Ikot Ubo; KTS = Ikot Osurua;

(Udotong, 2000).

The physicochemical analysis of the wetland soils also showed the soil texture to be such as provides good rooting environment for crops and good aerobic conditions for the proliferation of microorganisms (Brady, 1984). These results followed the same trend for wetland soils in Southern Nigeria (Esshiet, 1994). The wetland soils are generally acidic with pH ranges of normal agricultural soils. According to Landon (1984), solubilities of certain elements in quantities toxic to growth of plants is uncommon for soils with these pH ranges. These pH ranges also favour nitrification and nitrogen fixing activities.

The wetland soils under study generally have low levels of organic matter and total available nitrogen. Nitrogenous fertilizers are therefore recommended as good source of nitrogen for these soils. Crop residues should be ploughed back into the soil after harvesting of crop, to help maintain high level of soil organic matter. Organic matter and nitrogen serve as the main source of energy for microbial activities and tend to primarily encourage above-ground vegetative growth (Nester *et al*, 1983; Brady, 1984).

The ECEC of the wetland soil showed low values below the critical value of 20.0 mg/kg by FAWR (1990). This implies that the soils have poor capacity to store nutrients for crop use. Ability to maintain high organic matter level can help such poor soil state. Available potassium, sodium and phosphorus levels in these soils have been shown to promote proper growth of crops (Fagbami, 1994).

Statistically, the physicochemical analysis of the inland wetland soils of Ikot EKpene showed no correlation in interactions involving soil pH and season as well as particle size distribution and season.

The micronutrients were significantly different ($p > 0.01$); also interactions between micronutrients and seasons as well as sampling locations were significantly different ($P>O.01$). There was significant difference among microorganisms isolated from the wetland soils of Ikot Ekpene Local Government Area at ($P > 0.01$). Interaction between microbes and seasons as well as microbes and depths both revealed significant differences ($P > 0.01$).

CONCLUSION

The results of the present study have shown that the microbiological and physicochemical characteristics of the vast inland wetland soils in Ikot Ekpene can support sustainable agricultural activities. With effective soil conservation/management strategies, these hitherto unexploited wastelands can be put to effective/productive agricultural use.

REFERENCES

Alexander, M. (1985). *Introduction to Soil Microbiology* (2nd edition). Wiley Eastern Limited, New Delhi. 3 - 102.

Anderson, T. H. and Domsch, K. H. (1983). The metabolic quotient for CO2 as a Specific activity parameter to assess the effects *of* environmental conditions, such as pH, on the microbial biomass of forest soils. *Soil Biology and Biochemistry* 27:393 -395.

Anderson, J. M. and Ingram, J. S. I. (1993). *Tropical Soil Biology and Fertility:* A Handbook of Methods. (2nd edition). C. A. B. International, United Kingdom. pp. 47 - 49.

Andriese, W. (1986). Area and distribution: *The wetland* and *rice in subsaharan Africa;* in: Juo, A. S. R. and Lowe, J. A. (eds). International Institute of Tropical Africa - (IITA), Ibadan, Nigeria. Pp. 15 - 29.

Association of Official Analytical Chemists (AOAC) (1990): *Methods of Analysis* (12th edition), AOAC, Washington D.C.

Atlas, R. M. and Bartha, R. (1998). *Microbial Ecology: Fundamentals and Applications*

(4th edition). Benjamin / Cummings Publishing Company, California. pp. 511 - 602.

Barnet, H. L. and Hunter, B. B. (1987). *Ilustrated Genera of Imperfect Fungi* (4th edition). Macmillan Publishing Company, U. S.A.

Bouyoucous, G. J. (1962). Improved hydrometer method for making particle size analysis of soils. *Agronomy Journal* 54: 464-465.

Brady, N. C. (1984). *The Nature and Properties of Soils.* Macmillan Publishing Company, New York. Pp.10-593.

Bray, R. H. and Kurtz, L. T. (1945). Determination of total organic and available forms of phosphorus in soils. *Soil Science* 59: 39-54.

Collins, O. H. and Lyne, F. M. (1976). *Microbiological Methods.* Butterworth and Company Limited, Great Britain.

Cruickshank, R; Duguid, J. P; Mamion, R. Pi and Swain, R. H. A (1975:4). *Medical Microbiology.* ll. Churchill, Livngstone, London.

Demain, A L. and Davies, J. E. (eds) (1999). *Manual of Industrial Microbiology and Biotechnology* (2nd edition). American Society for Microbiology Press, Washington, DC.

Domsch, K. H, Gams, H. and Anderson, T. H. (1980). *Compendium of Soil Fungi.* Academic Press, London and New York.

Eka, O. U. and Fogathy, N. M. (1972). Descriptive studies on a *Streptomyces* species: part 1 Description and some properties of the microorganisms. *West African Journal of Biological and Applied Chemistry* 3 (5): 17-11.

Eshiett, E. T. (1992). Physicochemical, morphological and mineralogical characteristics of selected humid region profiles in Southeastern Nigeria. In: Kimble, J. M. (ed). Proceedings of the Eighth International Soil Correlation Meeting on Characterization, Classification and Utilization of Wet soils. Soil Conservation Service, USA. Pp. 100 105.

Eshiett, E. T. (1994). The Wetlands of Nigeria: distribution, characterization and traditional land use practice. Proceeding of the 21st Annual Conference of the Soil Science Society of Nigeria, University" of Uyo, Akwa Ibom State. 30th Jan -4th Feb. 1994 Pp. 1-19

Fagbamii A. (1994). Distribution and characterization of the Nigeria coastal soils and their management for sustainable agriculture. Paper presented at the 21st Annual Conference of Soil Science Society of Nigeria, University of Uyo. 30th Jan-4th February. 1994.

Federal Ministry of Agriculture, Water Resources and Rural Development. (FAWR) (1990). *Literature Review on Soil Fertility Investigations in Nigeria.* (FAWR). Lagos, Nigeria.

Gopal, Hi Turner, R. Ei Wetzel, R. G. and Whigham, D. F. (eds) (1982). *Wetlands: Ecology and Management.* National Institute of Ecology and International Scientific Publications, India. PP514.

Harrigan, W. F. and McCance, M, E. (1976). Laboratory *methods in Food and Dairy Microbiology.* Academic Press, London.

Holt, J. G., Kieg, N. R, Sneath, P. H. A., Staley, J. T. And Williams, S. T. (1994). *Bergey's Manual of Determinative Bacteriology* (9th edition) Williams and Wilkins Publishers, Baltimore, USA.

Jackson, M. L. (1962). *Soil Chemical Analysis.* Prenctice Hall, Englewood cliffs, New Jersey. Pp.110-112.

Kamalu, O. J. and Isirimah, N. O. (1992). A survey of organic matter status in major soils of the Niger Delta, Nigeria, *Nigerian Journal of Crop, Soil and Forestry.* 2(1): 77-84.

Landon, J. R. (ed.) (1994). *Booker Tropical Soil Manual: A Handbook for Soil Survey and*

Agricultural Land Evaluation in the Tropics and Sub-tropics. Booker Agriculture International Limited, England Pp. 113-157.

Mitsch, W. J. (1997). *Wetlands.* McGraw - Hill Encyclopedia of Science and Technology (8 edition). McGraw - Hill Inc. New York. 19:76-518.

Murphy, J. and Riley, J. P. (1962). Trace metal speciation analytical methods and problems, *Analytical Chemistry,* Act 227. Pp. 31-36.

Nester, E. W., Roberts, C. E., Lidstrom, M. E. and Nester, M. T. (1983). *Microbiology* (3rd edition). Saunders College Publishing, New York. Pp. 644-668.

Peters, S. W. (ed.) (1989). *Akwa /born State; Physical Background, Soils, Land Use and Ecological Problems:* Technical Report on Soil and Land Survey. Pp. 60- 120.

RPI (1985). Environmental Baseline Studies for the Establishment of control criteria and standards against petroleum - related Pollution in Nigeria. Final Report submitted to the Nigerian National Petroleum Corporation (NNPC), Lagos.

Sokal, R. R. and Rolf, F. J. (1981). Biometry: The any, New York, U.S.A.

Principle and Practice of Statistics in Biological Research (2nd edition). W. H. Freeman Company, New York, U.S.A.

Udo, E. J. and Ogunwale, J. A. (1986). *Laboratory Manual for the Analysis of Soil, Plant and Water Samples* (2nd edition). University Press, Ibadan.

Udotong, I. R. (2000). Environmental Monitoring and Effect of Petroleum Production Effluent on Some Biota of the Lower Qua Iboe River Estuary. Ph. D Thesis submitted to Rivers State University of Science & Technology, Nkpolu, Port Harcourt, Nigeria.

Udotong I. R. and Akpanekon, O. J. (2006a). Microbiological and physicochemical studies of wetland soils in Eket, Nigeria. In press.

Udotong I. R. and Akpanekon, O. J. (2006b). Microbiological and physicochemical studies of inland wetland soils in Itu, Nigeria. In press.

Walkley, A. and Black, I. A. (1934). An examination of the Degtjereff method for determining soil organic matter and a proposed modification of the chromic and titration method. *Soil Science* 37:29-38.