World Academy of Science, Engineering and Technology
International Journal of Biomedical and Biological Engineering
Vol:2, No:8, 2008

Microbiological and Physicochemical Studies of Wetland Soils in Eket, Nigeria

Ime R. Udotong, Ofonime U. M. John, and Justina I. R. Udotong

***Abstract*—**The microbiological and physicochemical characteristics of wetland soils in Eket Local Government Area were studied between May 2001 and June 2003. Total heterotrophic bacterial counts (THBC), total fungal counts (TFC), and total actinomycetes counts (TAC) were determined from soil samples taken from four locations at two depths in the wet and dry seasons. Microbial isolates were characterized and identified. Particle size and chemical parameters were also determined using standard methods. THBC ranged from 5.2 (±0.17) x10^6 to 1.7 (±0.18) x10^7 cfu/g and from 2.4 (±0.02) x10^6 to 1.4 (±0.04) x10^7cfu/g in the wet and dry seasons, respectively. TFC ranged from 1.8 (±0.03) x10^6 to 6.6 (± 0.18) x10^6 cfu/g and from 1.0 (±0.04) x10^6 to 4.2 (± 0.01) x10^6 cfu/g in the wet and dry seasons, respectively .TAC ranged from 1.2 (±0.53) x10^6 to 6.0 (±0.05) x10^6 cfu/g and from 0.6 (±0.01) x10^6 to 3.2 (± 0.12) x10^6 cfu/g in the wet and dry season, respectively. *Acinetobacter, Alcaligenes, Arthrobacter, Bacillus, Beijerinckja, Enterobacter, Micrococcus, Flavobacterium, Serratia, Enterococcus,* and *Pseudomonas species* were predominant bacteria while *Aspergillus, Fusarium, Mucor, Penicillium,* and *Rhizopus* were the dominant fungal genera isolated. *Streptomyces* and *Norcadia* were the actinomycetes genera isolated. The particle size analysis showed high sand fraction but low silt and clay. The pH and % organic matter were generally acidic and low, respectively at all locations. Calcium dominated the exchangeable bases with low electrical conductivity and micronutrients. These results provide the baseline data of Eket wetland soils for its management for sustainable agriculture.

***Keywords*—**Wetland soils, Microbial counts, physicochemical characteristics, Sustainable agriculture.

I. Introduction

WETLANDS are regarded as important ecosystems which are transitional between open water and terrestrial ecosystems. They are endowed with specific structural and functional attributes performing major ecological roles in the biosphere [1]. They have been recognised as peatbogs, grass and sedge marshes, floodplains consisting of recent alluvial deposits bordering rivers, inland valleys, shallow ponds, mudflats and littoral areas of larger bodies of water which can be grouped into naturally occurring and man-made or anthropogenic wetlands [2] [3] Wetland soils constitute vast, under-exploited and sometimes undiscovered ecologies in Nigeria [4]. Studies carried out on selected wetlands in parts of southeastern Nigeria have shown that wetlands in Nigeria have considerable agricultural potentials [5], [3], [4]. The declining productivity from upland agriculture therefore poses a compelling need to expand arable cropping into the country's vast and hitherto little exploited wetland resources which can provide the much needed sustainable production on account of their inherent soil fertility – maintaining mechanisms. However, the characteristics of the wetland vary widely in accordance with the multiplicity and diversity of ecologies with which the wetlands are associated [4]. The wetland soils in Eket receives industrial wastes and effluent from Mobil Producing Nigeria Unlimited, the second largest oil and gas company in Nigeria after shell petroleum development company. There has been paucity of information on the microbiological and Physico-chemical characteristics of this wetland in general and the Qua Iboe River wetlands in particular. The aim of this study therefore was to provide some baseline data for sustainable management of Eket wetland soils.

I. R. Udotong is with the Department of Microbiology, University of Uyo, P.M.B.1017, Uyo, Akwa Ibom State, Nigeria. (Phone: +234-8023008640) He is currently on Sabbatical Leave at Applied Ecology Dept; Environmental Systems Division, Snamprogetti S.p.A, Via Toniolo, 1-61032 Fano (PU), Italy (phone: +39 0721 1682 227, e-mail: ime.udotong@usicltd.com).

O. U. M. John is with the Department of Microbiology, University of Uyo .P.M.B.1017, Uyo, Akwa Ibom State, Nigeria (e-mail: preciousjohn2006@yahoo.com).

J. I. R. Udotong is with the Department of Biochemistry, University of Uyo, P. M. B. 1017, Uyo, Akwa Ibom State, Nigeria (e-mail: justina.udotong@usicltd.com).

II. Materials and Methods

A. Study Area

The study area comprises wetland sites distributed along Atabong, Uqua, Usung Inyang and Ikot Ebok in Eket local Government area [Fig. 1]. The land type of the sampling locations can be described as being nearly level to gently undulating slopes of 0-3^o, which provides a very stable physiographic environment for relatively uniform parent materials. The vegetation of the sampling locations comprises of grasses, ferns, oil and raffia palms [6].

B. Sample Collection

Soil samples were collected at 2 depths (0-15cm and 15-30cm) from four locations (Atabong, AT; Uqua, UQ; Usung Inyang, UI; and Ikot Ebok, IE) along a transect in the valley of Qua Iboe River [Table I]. The soil samples were collected as in [7], during the wet and dry seasons into labeled sterile polyethene bags and taken in ice-packed coolers to the laboratory for microbiological and physicochemical analysis.

C. Microbiological Analysis

(i) Serial Dilution

Ten-fold Serial dilutions of the soil samples were made as in [8], [9].

(ii) Inoculation and Incubation

One milliliter of appropriate ten-fold serial dilutions of the soil sample were Inoculated onto Nutrient agar (Oxoid CM 314), Reinforced Clostridial Agar Oxoid CM 149, 151), Malt Extract Agar (Oxoid) and Sabouraud Dextrose Agar plates in triplicates using pour plate methods [8], [9] and spread plates methods [10]. Soil plate technique [11] and [10] were also used for the isolation of Actinomycetes using the Starch Nitrate Agar. Inoculated plates were incubated at 28±2°C for 18-24 hours and 48-72 hours for the enumeration of total heterotrophic bacteria, fungi and Actinomycetes respectively. 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 agar media. Pure cultures were preserved on Nutrient agar slants and stored in the refrigerator (4^0C+2 ^{0}C) and at ambient temperature 28^O C $^+$2^{O}C) for further tests.

(iv) Characterization and Identification of Microbial Isolates

Pure cultures of microbial isolates were identified based on cultural parameters, microscopic techniques and biochemical tests including carbohydrate utilization [12]. Identification of the bacterial isolates was accomplished by comparing the characteristics of the cultures with that of known taxa as in [13]. Characterization and identification of fungal isolates was carried out as in [14], [15]. Actinomycetes were characterized and identified as in [11].

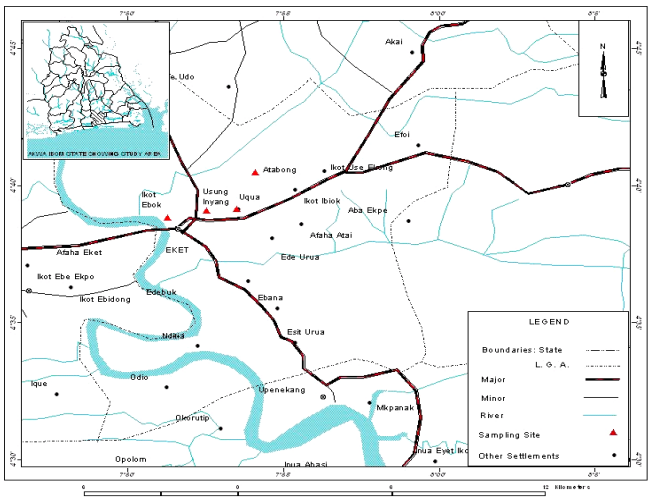

Fig. 1 Eket local government area showing sampling sites

D. Physicochemical Analysis of Soil Samples

Particle size analysis was done using the Bouyoucous Hydrometer method [16]. The pH of soil samples was determined as in [17]. Electrical Conductivity of the Soil Sample was determined as in [18]. Exchangeable cations were determined as in [18], [19]. Total nitrogen in the soil sample was determined by Microkjedahl digestion and distillation methods as in [18]. Available phosphorus was determined by the Bray No. 1 method [20] and Blue Molybdocolometric method [21]. Effective Cations Exchange Capacity was determined as in [6]. Total Organic Matter Contents was determined as in [22], while the Micro nutrients (Heavy metals) of the soil was determined using the Atomic Absorption Spectrophotometer (UNICAM AA 919 model) [19].

E. Statistical Analysis

The statistical analyses employed in this work include standard deviation, analysis of variance and correlation [23].

TABLE I
SAMPLING POINTS AND THEIR COORDINATES

S/N	Sampling point	Sampling location/code	Coordinates	
			Lat	Long
1	Upper slope	Atabong(AT)	7^0 57^1	4^0 41^1
2	Middle Slope	Uqua(UQ)	7^0 57^1	4^0 40^1
3	Lower Slope	Usung Inyang(UI)	7^0 56^1	4^0 39^1
4	Bottom Slope	Ikot Ebok(IE)	7^0 55^1	4^0 39^1

III. RESULTS

A. Microbiological Analyses

i. Microbial Counts

The microbial counts of microorganisms isolated from the wetland soils of Eket are as shown on Table II. Total heterotrophic bacterial counts (THBC), ranged from 5.2 (±0.17) x 10^6 to 1.7 (±0.18) x 10^7cfu/g in the wet season and from 2.4 (±0.02) x 10^6 to 1.4 (±0.04) x 10^7cfu/g in the dry season. Total fungal counts (TFC) ranged from 1.8 (±0.03) x 10^6 to 6.6 (±0.18) x 10^6cfu/g in the wet season and from 1.0 (±0.04) x 10^6 to 4.2 (±0.01) x 10^6cfu/g in the dry season. Total actinomycetes counts (TAC) ranged from 1.2 (±0.53) x 10^6 to 6.0 (±0.05) x 10^6cfu/g in the wet season and from 0.6 (±0.01) x 10^6 to 3.2 (±0.12) x 10^6cfu/g in the dry season. The count revealed THBC as the highest count, followed by fungal counts and Actinomycetes as the least. Generally, the study revealed a decrease in microbial counts of the isolates with increase in soil depth in the wet and dry seasons.

ii. Microbial Isolates from Eket Wetland Soils

The bacterial isolates of Eket wetland soils belonged to the genera *Acinetobacter, Alcaligenes, Arthrobacter, Bacillus, Beijerinckia, Enterobacter, Micrococus, Flavobacterium, Serratia, Enterococcus and Pseudomonas.* The fungal isolates were mostly of the genera *Aspergillus, Fusarium, Mucor, Penicillium and Rhizopus,* while *Actinomycetes were of the genera Streptomyces* and *Norcadia.*

TABLE II
MICROBIAL COUNT ISOLATES FROM EKET WETLANDSOIL: (WET AND DRY SEASONS)

Sample code	Depth (CM)	THBC ($X10^6$, $X10^7$cfu/g		(TAC) $X10^6$ cfu/g)		(TFC) ($X10^6$cfu/g)	
		WET SEASON	DRY SEASON	WET SEASON	DRY SEASON	WET SEASON	DRY SEASON
AT	0-15	1.1±0.23 $X10^7$	8.6±0.01 $X10^6$	2.6±0.53	2.6±0.53	5.4±0.15	1.4±0.33
AT	15-30	5.2±0.17 $X10^6$	2.4±0.02 $X10^6$	1.4±0.44	1.0±0.09	2.2±0.00	1.0±0.04
UQ	0-15	1.4±0.19 $X10^7$	1.1±0.12 $X10^7$	3.0±0.87	2.2±0.31	5.8±0.17	2.6±0.57
UQ	15-30	7.0±0.1 $X10^6$	4.2±0.21$X10^6$	1.6±0.11	1.2±0.10	2.6±0.14	1.6±0.25
UI	0-15	1.6±0.15 $X10^7$	1.3±0.18 $X10^7$	6.0±0.05	3.2±0.12	6.6±0.18	3.6±0.25
UI	15-30	9.2±0.01 $X10^6$	5.6±0.26 $X10^6$	2.0±0.02	1.4±0.02	3.2±0.09	2.0±0.04
IE	0-15	1.7±0.18 $X10^7$	1.4±0.04 $X10^7$	2.3±0.05	1.6±0.23	3.6±0.21	4.2±0.01
IE	15-30	9.8+0.33 $X10^6$	6.6+0.01 $X10^6$	1.2+0.53	0.6+0.01	1.8+0.03	2.2+0.11

AT = Atabong; UQ = Uqua; UI = Usung Inyang; IE = Ikot Ebok; THBC = Total Heterotrophic Bacterial Count; TFC = Total Fungal Count; TAC = Total Actinomycetes Count

TABLE III
PARTICLE SIZE DISTRIBUTION OF EKET WETLAND SOIL (WET AND DRY SEASONS)

Sample code	Depth (cm)	SAND (%) Wet Season	SAND (%) Dry Season	CLAY(%) Wet Season	CLAY(%) Dry Season	SILT(%) Wet Season	SILT(%) Dry Season
AT	0-15	89.2±0.01	88.2±0.11	8.2±0.05	6.2±0.02	2.6±0.02	5.6±0.02
AT	15-30	84.4±0.02	84.4±0.12	10.8±0.02	9.0±0.01	4.8±0.02	5.8±0.02
UQ	0-15	82.2±0.05	82.0±0.10	10.2±0.05	9.2±0.02	7.6±0.02	8.8±0.02
UQ	15-30	76.4±0.02	78.4±0.01	14.4±0.10	12.4±0.03	9.2±0.02	9.2±0.02
UI	0-15	77.6±0.02	79.6±0.12	11.4±0.05	9.4±0.05	11.0±0.04	11.0±0.08
UI	15-30	76.0±0.01	76.8±0.01	14.2±0.01	13.0±0.02	9.8±0.09	9.2±0.04
IE	0-15	73.8±0.03	75.8±0.02	13.8±0.02	11.8±0.02	12.4±0.06	12.4±0.06
IE	15-30	69.8±0.05	71.8±0.04	18.4±0.06	17.2±0.01	11.8±0.02	11.0±0.01

AT = Atabong, UQ = Uqua, UI = Usung Inyang, IE = Ikot Ebok

TABLE IVA
CHEMICAL ANALYSIS OF EKET WETLAND SOIL (WET SEASON)

SAMPLE CODE	DEPTH (cm)	pH	EC (ds/m)	Organic matter %	N %	AV.P. (mg/kg)	Ca	Mg (cmo^1/kg)	Na	K	EA
AT	0-15	5.6±0..01	0.04±0.01	3.18±0.00	0.10±0.00	12.33±0.00	2.4±0.0	1.4±0.00	0.05±0.00	0.08±0.00	1.81±0.(
AT	15-30	5.5. ±0.01	0.03±0.00	2.78±0.02	0.08±0.01	10.20±0.00	0.96±0.01	0.48±0.02	0.05±0.00	0.07±0.00	2.96±0.(
UQ	0-15	5.6±0.03	0.04±0.00	3.35±0.00	0.10±0.00	14.33±0.00	3.36±0.00	1.80±0.00	0.04±0.01	0.12±0.00	2.70±0.(
UQ	15-30	5.6±0.01	0.03±0.00	3.19±0.00	0.10±0.00	9.90±0.02	1.68±0.00	1.10±0.00	0.04±0.00	0.08±0.01	2.70±0.(
UI	0-15	5.8±0.01	0.04±0.00	3.39±0.00	0.11±0.00	16.66±0.00	4.32±0.00	2.00±0.02	0.06±0.00	0.06±0.02	1.59±0.(
UI	15-30	5.8±0.01	0.03±0.00	3.20±0.00	0.10±0.00	17.66±0.00	2.64±0.00	1.80±0.00	0.05±0.00	0.08±0.00	2.76±0.(
IE	0-15	5.6±0.02	0.03±0.00	4.17±0.02	0.12±0.04	20.36±0.2	4.56±0.04	2.1±0.01	0.05±0.00	0.07±0.00	2.33±0.(
IE	15-30	5.6±0.00	0.02±0.00	3.22±0.00	0.09±0.00	19.33±0.00	1.96±0.00	1.30±0.00	0.07±0.02	0.06±0.02	3.29±0.(

AT = Atabong, UQ = Uqua, UI = Usung Inyang, IE = Ikot Ebok, N = Nitrogen, Av. P = available Phosphorus; Ca = Calcium Mg. Magnesium; Na = sodium; K = Potassium; EA = Exchangeable Acids; ECEC = Exchangeable Cation Exchange Capacity; BS = Base Saturation; EC = Electrical Conductivity

TABLE IVB
CHEMICAL ANALYSIS OF EKET WETLAND SOIL (WET SEASON)

SAMPLE CODE	DEPTH (cm)	pH	EC (ds/m)	Organic matter %	N %	AV.P. (mg/kg)	Ca	Mg (cmo^1/kg)	Na	K	EA	ECEC	B.S %
AT	0-15	5.4±0.01	0.05±0.02	2.01±0.01	0.05±0.00	10.2±0.00	1.96±0.00	1.3±0.00	0.07±0.04	0.06±0.00	3.24±0.00	6.68±0.00	50.8. ±0.00
AT	15-30	5.4±0.02	0.05±0.01	1.6±0.011	0.04±0.02	9.3±0.00	0.70±0.01	0.30±0.01	0.05±0..20	0.29±0.00	0.4±0.00	1.74±0.01	77.0±0.00
UQ	0-15	5.5±0.01	0.03±0.02	2.53±0.02	0.07±0.00	9.32±0.00	2.2±0.00	1.2±0.000	0.07±0.04	0.08±0..01	2.3±0.00	5.85±0.00	60.68±0.00
UQ	15-30	5.5. ±003	0.03±0.02	2.41±0.01	0..05±0.00	8.52±0.05	0.96±0.00	0.48.00	0.05±0.02	0.09±0.00	2.96±0.00	4.52±0.00	34.51±0.00
UI	0-15	5.6±0.02	0.03±0.02	3.01±0.02	0.08±0.00	14.3±0.00	3.36±0.02	1.8±0.00	0.06±0.00	0.12±0.00	2.7±0.00	8.04±0.02	66.4±0.00
UI	15-30	5.6±0.02	0.03±0.02	2.81±0.01	0.07±0.00	15.0±0.00	2.4±0.00	1.4±0.00	0.05±0.02	0.08±0.01	1.81±0.00	5.75±0.00	68.5±0.00
IE	0-15	5.5±0.01	0.03±2,00	3.82±0.05	0.10±0.04	18.4±0.1	3.6±0.02	1.8±0.00	0.07±0.04	0.19±0.00	0.85±0.00	6.49±0.00	87.2±0.00
IE	15-30	5.5±0.00	0.03.0.00	2.83±0.01	0.07±0.00	16.2±0.00	3.46.000	2.0±0.02	0.07±0.04	0.32±0.04	3.10±0.00	8.95±0.2	65.40.00

AT = Atabong, UQ = Uqua, UI = Usung Inyang, IE = Ikot Ebok, N = Nitrogen, Av. P = available Phosphorus; Ca = Calcium Mg. Magnesium; Na = sodium; K = Potassium; EA = Exchangeable Acids; ECEC = Exchangeable Cation Exchange Capacity; BS = Base Saturation; EC = Electrical Conductivity

TABLE V
MICRONUTRIENTS OF EKET WETLAND IN WET AND DRY SEASONS

SAMPLE CODE	DEPTH (CM)	COPPER (Cu) (mg/kg		ZINC (Zn) (mg/kg)		IRON (Fe) mg/kg		Manganese (Mg/kg)	
		Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season
AT	0-15	05±0.01	0.4±0.03	3.4±0.05	3.0±0.00	13.4±0.01	11.4±0.04	2.0±0.05	1.5±0.12
AT	15-30	0.5±0.01	0.4±0.03	3.1±0.00	3.0±0.01	13.6±0.02	11.4±0.04	2.0±0.01	1.2±0.07
UQ	0-15	0.7±0.1	0.5±0.02	3.1±0.00	3.1±0.00	24.3±0.00	22.0±0.04	1.4±0.03	1.2±0.05
UQ	15-30	0.6±0.00	0.5±0.02	3.0±0.01	3.1±0.00	25.2±0.00	22.1±0.07	1.4±0.03	1.1±0.01
UI	0-15	0.6±0.00	0.5±0.02	3.8±0.00	3.5±0.04	36.0±0.01	32.2±0.00	1.4±0.03	1.3±0.03
U	15-30	0.6±0.00	0.5±0.02	3.8±0.00	3.5±0.11	38.0±0.01	32.2±0.00	1.4±0.03	1.3±0.05
IE	0-15	0.6±0.00	0.5±0.02	3.8±0.00	3.5±0.00	38.0±0.01	32.2±0.05	1.4±0.03	1.3±0.01
IE	15-30	0.6±0.00	0.5±0.02	3.9±0.05	3.7±0.01	38.0±0.01	32.5±0.07	1.5±0.02	1.3±0.01

AT = Atabong, UQ=Uqua, UI= Usung Inyang, IE= Ikot Ebok

iii. Physical Analysis

The particle size of the wetland soils is as shown on Table III. It revealed the texture of the soils as varying from sandy to loamy sand and sandy clay loam in both seasons with the sand, clay and silt fractions that ranged between 69.8 (±0.05) to 89.2 (±0.01)%, 6.2 (±0.02) to 18.4 (±0.06)%, and 2.6 (±0.02) to 12.4 (±0.06)% respectively in both seasons.

iv. Chemical Analysis

Tables IVa, b, and V show the chemical analyses of the wetland soils in the wet and dry seasons. The pH ranged between 5.4 (±0.01) to 5.8 (±0.01), electrical conductivity; 0.02 (±0.00) to 0.05 (±0.02), organic matter; 1.6 (±0.11) to 4.17 (±0.02)%, Nitrogen; 0.04 (±0.02) to 0.12 (±0.04). The micronutrients revealed highest concentration of iron 11.4 (±0.04) to 38.0 (±0.01) mg/kg) and least concentration of copper 0.4(±0.03) to 0.07 (±0.01) mg/kg) in both seasons. The chemical analysis showed the wetland soils of Eket as following similar trend for wetland soils in Itu and Ikot Ekpene in particular and southern Nigeria in general [24], [25], [4] and [26]. The chemical analysis showed indication of the soil's suitability for land utilization for agricultural practices [27].

IV. DISCUSSION

This work on the microbiological and physicochemical studies of wetland soils in Eket, Nigeria was designed to provide baseline data on which the potentials of this vast unexploited wetland soils can be maximised for sustainable agriculture. The wetland soils understudy revealed the Heterotrophic bacteria as having the highest occurrence. Fungi constituted the second highest number of microbes that inhabit the wetland soils while the Actinomycetes were the least among the three groups of microorganisms isolated from the wetland soils in both seasons. Occurrence of the heterotrophic bacteria as the highest occurring organisms could be attributed to the tolerance of these microbes to wide variations of the soil properties, which prevailed in both seasons. It followed the same trend reported for soil bacterial populations [27]. The high fungal counts could be attributed to the acidic nature of these soils in both seasons, since fungal growth are enhanced by the acid nature of an environment [28]. Actnomycetes, occurring least among the isolates in both seasons could be attributed to the acidic nature of the wetland soils, which does not favour high proliferation of Actinomycetes [27]. The results from these studies showed a decrease in the microbial counts with increase in soil depth: microbial counts were higher in surface soils (0-15 cm) than in the sub-surface soils (15-30cm). This could be attributed to the higher availability of favourable growth factors such as organic matter and oxygen at the surface soil (0-15cm) than at the sub-surface soil levels (15-30cm). Results also showed increase in the microbial counts during the wet season and a decrease in the dry season. This also could be attributed to the slight variations in the properties of the wetland soils due to climatic changes in both seasons [29]. The microbial counts obtained from this study followed the same trend with microbial counts of Ikot Ekpene and Itu wetland soils [24], [25] in particular and the Niger Delta Region [26] in general.

The microbiological study of the wetland soils along the valley of Qua Iboe River in Eket has revealed the wetland soils as playing host to various genera of bacteria Actnomycetes and fungi. Soil microorganisms play subordinate role to plants as they play a critical role in organic matter decomposition, stabilizing of soil structure as well as mineral cycling [30], [31]. Species of the various microbial isolates from the wetland soils under study (e.g. *Arthrobacter, Bacillus, Pseudomonas, Beijerinckia)* have been reported to be involved in these important activities [30],[31]; [32], [33] and [34]. The microbial isolates from the wetland soils under study compare favourably with the microbial isolates from Itu and Ikot Ekpene wetland soils [24], [25]. Statistically, the wetland soils showed significant difference among the isolates at $P>0.01$, significant difference between the isolates and seasons at $P<0.05$ and significant difference between microbes and soil depth at $P>0.01$.

The characteristics of a soil largely determine its utilization [35]. Thus, from the results of this study, the texture of these wetland soils have shown the soils as having excellent physical conditions for seedbed preparation, but are fragile because of the sandiness of the surface soils. Hence, minimum or zero tillage should be emphasized to reserve the soil structure. Practices such as contour tillage should be emphasized to preserve the soil structure. Practices such as contour tillage, strip cropping and terracing should be employed to prevent or control erosion along the sloping fields of the wetland soils.

The soils under study also showed a range of acidity as well as deficiency of basic cation nutrients. Liming is therefore

required in small doses to check these. overliming should however be avoided in order to prevent induced deficiency of micronutrients such as copper, iron, zinc and manganese as well as available phosporus [36]. Deficiency of potassium was observed at some locations during the course of this study. Thus, potassium fertilizers are strongly recommended especially for cereals and root crops like maize, cassava and yams. The study also revealed deficiency of nitrogen at all the sampling locations. Nitrogenous fertilizers such as calcium ammonium nitrate are recommended for these soils. Clear evidence of phosphorus deficiency was observed for these wetland soil locations. Phosphatic fertilizers should therefore be applied to these soils to achieve high yield.

Generally, since the soil contains high fraction of sand, to maintain the nitrogen level and prevent losses by leaching in the soil during the growing rainy season, split application of nitrogen and potassium fertilizers are necessary. The wetland soils under study revealed low organic matter content. To achieve the maintenance of a high level of soil organic matter in these wetland soils, crop residues should be ploughed back into the soil after harvesting of crops. The high percentage base saturation expresses low degree of leaching in these soils. This could be attributed to the nature of colloid which constitutes the soil [37]. Statistically, the physicochemical properties also revealed that there was no correlation in the interactions which involved soil pH and season as well as soil particle size distribution and season. It is thus expressed that the pH and particle size do not necessarily depend on the seasons, but on other factors such as parent rock materials. Statistics also showed significant difference of the micronutrient at $P>0.01$, interaction between micronutrient and seasons at $P>0.01$ and interaction between micronutrients locations at $P>0.001$.

V. Conclusion

The microbiological and physicochemical study of the wetland soils in Eket during the cause of this study revealed their microbiological and physicochemical characteristics as being suitable for arable crop cultivation. This involves the cultivation of major arable crops such as cassava, yam, cocoyam and vegetables. The wetland soils have also proved to support the cultivation of rice [38]. However, the planting of tree crops such as rubber, coconut and oil palms should also be encouraged on these soils since these crops tolerate acidic conditions as revealed by soils in this study. With the data provided by this study, in order to efficiently utilize this important ecosystem, animal production such as fish and shellfish production along side crop production should be embraced at the wetland sites.

References

[1] A.W.A.Edwards. "Wetlands in southern Nigeria" in Nigerian¬¬¬_Wetlands: T. V.Akpata and D. U. U.Okoli, Eds.Ibadan: Emmi Press Samanda, 1990,Pp. 27-34.

[2] B.Gopal;R.E. Turner;R.G. Wetzer and D.F. Whigham. Eds .Wetlands: Ecology and Management. India: National Institute of Ecology and International Scientific Publications, 1982, Pp. 514.

[3] E.T.Eshiett. "Physicochemical, morphological and mineralogical characteristics of selected humid region profiles in Southeastern Nigeria" in proceedings of the Eighth International Soil Correlation Meeting on Characterization, Classification and Utilization of Wet soils. J.M. Kimble, Ed. USA: Soil Conservation Service, 1992, Pp. 100 – 105.

[4] E.T.Eshiett. 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

[5] E.T.Eshiet, J.A.I.Omueti and A.S.R. Juo . Characterization of wetland soils supporting rice production in South Eastern Nigeria. Thailand Journal of Agricultural Science Vol.2, Pp. 35-50, 1988.

[6] S.W.Peters Ed. "Akwa Ibom State; Physical Background, Soils, Land Use and Ecological Problems" in Technical Report on Soil and Land Survey. 1989, Pp. 60-120.

[7] J.M.Anderson, and J.S.I. Ingram, Tropical Soil Biology and Fertility: A handbook of Methods. 2nd edition .United Kingdom: C. A. B. International, 1993, Pp. 47 – 49.

[8] O.H.Collins and F.M. Lyne. Microbiological Methods .Great Britain: Butterworth and Company Limited, 1976.

[9] E.F.Harrigan and M.E. McCance .¬Laboratory Methods in Food and Dairy Microbiology. London: Academic Press, 1976.

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

[11] O.U.Eka and N.M. Fogathy. Descriptive studies on a Streptomyces Species part 1. Description and some properties of the microorganisms. West African Journal of Biological and Applied Chemistry Vol. 3, no.5, Pp. 11 – 17, 1972.

[12] R.Cruickshank, J.P. Duguid, R.P. Mamion, and R.H.A. Swain. Medical Microbiology. Vol II, London: Churchill, Livngstone, 1976.

[13] J.G.Holt; N.R. Kieg; P.H.A. Sneath, J.T. Staley and S.T. Williams. Bergey's Manual of Determinative Bacteriology. 9thedition, Baltimore, USA: Williams and Wilkins Publishers, 1994.

[14] K.H.Domsch,H.Gams and T.H. Anderson. Compendium of Soil Fungi London: Academy Press, 1980.

[15] H.L. Barnet and B.B. Hunter, Ilustrated Genera of Imperfect Fungi .4th Edition USA: Macmillan Publishing Company, 1987.

[16] G.J.Bouyoucous. Improved hydrometer method for making particle size analysis of soils.Agronomy Journal Vol. 54, Pp464-465, 1962.

[17] E.J.Udo and J.A. Ogunwale. Laboratory Manual for the Analysis of Soil, Plant and Water Samples. 2nd edition. Ibadan: University Press, 1986.

[18] M.L.Jackson. Soil Chemical Analysis .Englewood Cliffs, New Jersey: Prenctice Hall Inc. 1962, Pp. 110-112.

[19] Association of Official Analytical Chemists (AOAC). Methods of Analysis. 12th edition. Washington DC: AOAC, 1990.

[20] R.H.Bray and L.T. Jurtz . Determination of total organic and available forms of phosphorus in soils. Soil Science Vol. 59 ,Pp 39-54, 1945.

[21] J.Murphy and J.P. Rile. Trace metal speciation analytical Methods and Problems in Analytical Chemistry, Act 227, Pp. 31-36, 1962.

[22] A.Walkley and I.A. Black. An examination of the Degtjereff Method for determining Soil organic matter and a proposed modification of the chromic and titration method. Soil Science Vol.37, Pp.29-38, 1934.

[23] R.R.Sokal and F.J. Rolf. Biometry: The Principle and Practice of Statistics in Biological Research. 2nd edition. New York. USA: W. H. Freeman Company,1981.

[24] I.R.Udotong and O.J. Akpanekon (a). "Microbiological and Physicochemical studies of wetland soils in Itu, Nigeria". Nigerian Journal of Microbiology, to be published.

[25] I.R.Udotong and O.J. Akpanekon (b). "Microbiological and Physicochemical studies of inland wetland soils in Ikot Ekpene, Nigeria". Nigerian Journal of Microbiology., to be published.

[26] RPI. 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.1985

[27] N.C.Brady. The Nature and Properties of soils. New York: Macmillan Publishing Company, 1984, Pp. 10 – 593.

[28] E.Moore – Landecker. Fundamentals of the Fungi .3rd edition, New Jersey: Prentice Hall Inc., 1990.

[29] S. Higashida and K. Takao. Seasonal fluctuation patterns of microbial numbers in the surface soil of a grassland. Soil Science and Plant Nutrition, Vol.31,Pp. 113-121,1985.

[30] M.Alexander, Introduction to Soil Microbiology .2nd edition. New Delhi: Wiley Eastem Limited, 1985, Pp.3 – 102.

[31] R.M.Atlas and R. Bartha. Microbial Ecology: Fundamentals and Applications. 4th edition, CA: Benjamin/Cummings Publishing Company, 1998, Pp. 511 – 602.
[32] K.H.Nelson and C.R. Myers. Microbial Reduction of manganese and Iron: New approaches to carbon cycling. Applied and Environment Microbiology Vol.58, Pp.439-443, 1992.
[33] D.J. Hardman,M . Sharron and E.Stephen. Pollution: Ecology and biotreatment. New York: John Wiley and sons Inc. 1993, Pp.97-117.
[34] A.Brewer. The science of ecology. 2nd Edition, Philadelphia:Saunders Publishers,1994, Pp.589-598.
[35] J.Hassink. Effect of soil texture and structure on carbon and nitrogen mineralization in grassland soils". Biology and Fertility of Soils Vol.14,Pp.126-134, 1992
[36] J.R.Landon.Ed. Booker Tropical Soil Manual: A Handbook_for Soil Survey and Agricultural Land Evaluation in the Tropics and Sub-tropics. England:Booker Agriculture International Limited. 1994, Pp. 113-157.1994.
[37] N.O.Isirimah. Mineralogy, chemistry and fertility of Nigerian coastal soils. A paper presented at the 21st Annual Conference of Soil Science Society of Nigeria, University of Uyo. Jan. 31st – Feb. 4tt, 1994.
[38] E.T.Eshiet.;J.A.I Omueti and A.S.R. Juo . Status constraints and potentials of wetland rice cultivation in eastern Nigeria: A case study of three farming villages. Thailand Journal of Agricultural Science Vol. 24, no.3, Pp. 243-260.1991.

Ime R. Udotong was born in Ikpe Annang, Etim Ekpo LGA, Akwa Ibom State, Nigeria on 23 July 1960. He holds a Higher National Diploma (HND) in Applied Biology from Rivers State University of Science & Technology, Port Harcourt, Nigeria; Master of Philosophy (M.Phil) in Applied Microbiology (Waste Management option) and a Doctor of Philosophy (Ph.D) in Applied Microbiology (Environmental Monitoring & Impact Assessment option) from same University.

He was promoted an Associate Professor of Environmental Microbiology on 1st October 2002 and seconded from the Department of Microbiology, University of Uyo, Nigeria to work as the MANAGING DIRECTOR of University of Uyo Consultancy Ltd from 23rd August 2003 to 31st January 2008. Besides research and training at the undergraduate and post graduate levels, he has worked as Environmental Consultant / Expert to multi-national Oil & Gas companies in Nigeria and Europe. He is presently on Sabbatical leave at Applied Ecology Dept., Environmental Systems Division, Snamprogetti S.p.A., Via Toniolo, 1-61032 Fano (PU), Italy as ENVIRONMENTAL CONSULTANT / EXPERT with effect from 1st September 2008. He has published 22 articles in local and international Journals, 16 Technical Reports, 6 book chapters and 4 International and several Conference papers to his credit. His current research interest is in the Microbial ecology of and impacts of Oil & Gas E&P activities on wetland soils.

Dr. Udotong is a member of Nigerian Society for Microbiology (NSM), Nigerian Institute of Food Science & Technology (NiFST) and Nigerian Environmental Society (NES). As Environmental Consultant / Expert, he has consulted severally for Shell Petroleum Development Company of Nigeria Ltd (SPDC), Nigerian Agip Oil Company Ltd (NAOC), Mobil Producing Nigeria Ltd – a subsidiary of Exxon Mobil and Elf Petroleum Nigeria Ltd (EPNL).