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# Microbiological and Physicochemical Studies of Wetland Soils in Eket, Nigeria

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***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) x$10^6$ to 1.7 (±0.18) x$10^7$ cfu/g and from 2.4 (±0.02) x$10^6$ to 1.4 (±0.04) x$10^7$cfu/g in the wet and dry seasons, respectively. TFC ranged from 1.8 (±0.03) x$10^6$ to 6.6 (± 0.18) x$10^6$ cfu/g and from 1.0 (±0.04) x$10^6$ to 4.2 (± 0.01) x$10^6$ cfu/g in the wet and dry seasons, respectively .TAC ranged from 1.2 (±0.53) x$10^6$ to 6.0 (±0.05) x$10^6$ cfu/g and from 0.6 (±0.01) x$10^6$ to 3.2 (± 0.12) x$10^6$ 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.

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## 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°, 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 ($4^0$C+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].

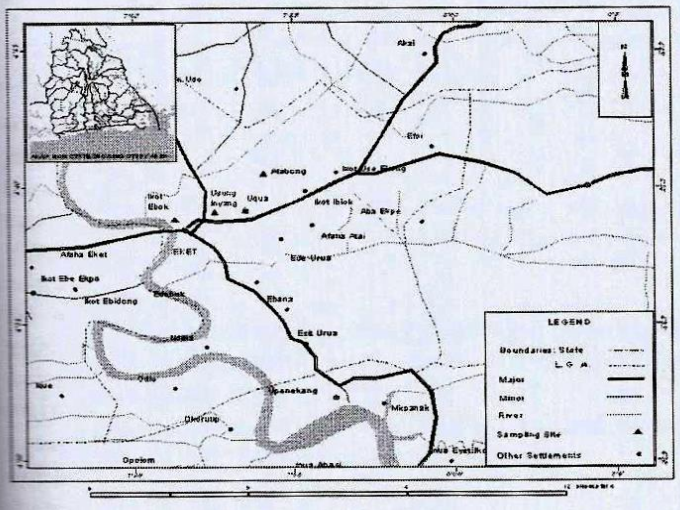


Fig. 1 Eket local government area showing sampling sites

*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 $10^7$cfu/g in the wet season and from 2.4 (±0.02) x $10^6$ to 1.4 (±0.04) x $10^7$cfu/g in the dry season. Total fungal counts (TFC) ranged from 1.8 (±0.03) x $10^6$ to 6.6 (±0.18) x $10^6$cfu/g in the wet season and from 1.0 (±0.04) x $10^6$ to 4.2 (±0.01) x $10^6$cfu/g in the dry season. Total actinomycetes counts (TAC) ranged from 1.2 (±0.53) x $10^6$ to 6.0 (±0.05) x $10^6$cfu/g in the wet season and from 0.6 (±0.01) x $10^6$ to 3.2 (±0.12) x $10^6$cfu/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.

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