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Microbiological, Physicochemical and Enzyme Activity Profile of Ayadehe Coastal Wetland Soils, Nigeria

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Authors' contributions

This work was carried out in collaboration between the authors. Author OUMJ designed the study, managed the analyses of the study, performed the statistical analysis and wrote the protocol and first draft of the manuscript. Author SIE managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Aims: The present study aimed to determine the microbiological, physicochemical and enzyme activities of Ayadehe Coastal wetland soils in Itu local government area of Akwa Ibom State, Nigeria to ascertain their potentials for effective management.
Study Design: Coastal wetland soils from three depths (0-15 cm, 15-30 cm and 30-45 cm) were assessed in the wet and dry seasons of 2016 and 2017.
Place and Duration of Study: The study was carried out at Ayadehe coastal wetland, Itu, Akwa Ibom state and the soil samples analysed at the Microbiology and Central Research Laboratories, University of Uyo, Uyo, Akwa Ibom state, Nigeria in 2016 and 2017.
Methodology: The isolation, enumeration, characterisation and identification of microbial isolates were carried out using cultural procedures. The physicochemical and enzyme activities of soils were assessed using standard procedures.
Results: Total heterotrophic bacterial and total Fungal counts from 0 – 45 cm soil depths ranged

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from 5.7 to 7.98 Log_{10}CFU g^{-1} in the wet and dry seasons. The nitrifying bacteria, phosphate solubilising bacteria and cellulolytic bacteria counts of the soils from 0 - 45 cm depth ranged from 0.0 to 5.6 Log_{10} CFU g^{-1} which was 1.01 to 1.05 times higher in the wet season than the dry season, and the difference was significant at p = 0.05. The bacteria from the wetland soils included members of the genera *Acinetobacter, Alcaligenes, Arthrobacter, Azotobacter, Bacillus, Beijirinckia, Cellulomonas, Flavobacterium, Micrococcus, Nitrobacter, Nitrosomonas, Proteus, Pseudomonas*, *Rhizobium, Sarcina, Serratia,* and *Staphylococcus.* The fungi belonged to the genera *Aspergillus, Cladosporium, Fusarium*, *Mucor, Penicillium,* and *Rhizopus*. The particle size distribution indicated the soil was sandy clay loam and the pH ranged between 6.0 ± 0 and 6.2 ± 0.01. Enzyme activities of soils also showed variations (p = 0.05) in the wet and dry seasons with strong positive linear correlations between dehydrogenase and microbial densities.

Conclusion: The favourable pH, the presence of diverse enzymes and the rich assemblage of microorganisms to carry out critical ecosystem services indicates the potential to support crop production.

Keywords: Coastal; wetland soils; microbiological; physicochemical; enzyme activities.

1. INTRODUCTION

A coastal wetland is an area that is located in the "transition zone" between dry land and open fresh, salty or estuarine/brackish water environment. They have the characteristics of both upland (high, dry land) and aquatic area with temporal or seasonal influence by both systems [1]. The physical, chemical, mineralogical and hydrological properties of wetland soils vary widely in accordance with the multiplicity and diversity of environmental, lithological and pedogenetic factors with which the wetlands are associated. These include the amount of rainfall received, leaching intensity, nature of parent materials from which the soils have been formed, the clay fraction mineralogy and position of the wetland on the landscape [2,3].

Wetland soils constitute vast, under-exploited and sometimes undiscovered ecologies in many countries, including Nigeria. In southeastern Nigeria, wetlands comprise about 22,895km^2. The region is characterized by heavy rainfall and the soil is acidic with texture revealing an increase in clay while sand fraction decrease with depth and silt fraction irregularly distributed. The acidic nature of the wetland soils which can influence soil biological community is consequence of the acidic nature of the parent rock coupled with the influence of the leached profile under high annual rainfall condition [2,3,4,5,6,7,8] Studies carried out on selected wetlands in parts of southern Nigeria have shown these wetland soils have considerable agricultural potentials for the production of rice, maize, dry season vegetables, early yam species and cocoyam [2,3,7]. Akwa Ibom State located in southern Nigeria is endowed with abundant wetlands where little or no crop production is practiced. The declining productivity from the upland agriculture, therefore, poses a compelling need to expand arable cropping into the unexploited and underutilized wetland resources which can provide the needed source for sustainable food production. Here, we assessed the characteristics of Ayadehe coastal wetland soils for use in crop production based on the presence of special microbial groups and enzyme activities regarded as potential biomarkers for soil fertility.

2. MATERIALS AND METHODS

2.1 Study Area

The study areas comprise coastal wetlands of Ayadehe in Itu local government area, Akwa Ibom State, Nigeria. It is located between latitudes 5°9' 39.98" and 5°11'8.01'' North and longitudes 8°2'5 .40" and 8°3'53.98" East. The vegetation of the study area comprises a tree of various kinds (e.g. Raphia palm), ferns, shrubs and grasses. The study area is characterized by a distinct wet season which lasts for at least seven months (April to October) and a dry season which lasts for five months (November to March). Mean annual rainfall is 3000 mm, and temperatures are uniform throughout the year with slight variations between 26° and 30°C.

2.2 Collection of Soil Sample

Composite soil samples were collected at three depths (0 - 15, 15 - 30 and 30 - 45 cm) with the aid of soil augers into labelled, unused sterile

polyethene bags and sterile plastic containers. The samples were transported to the University of Uyo Microbiology and Central Research Laboratories in ice chamber for microbiological, physicochemical and enzyme activity analysis. Sampling was carried out in the wet and dry seasons of 2016 and 2017. The dry and wet season sampling was carried out in the months of November to March and May to September respectively. Sampling was done at the beginning, peak and end of the season with a total of twelve times. All soil samples for microbiological analysis were analyzed within 24 hours after collection. The soil samples for physicochemical analysis prior to analysis were air-dried and sieved using a two millimetre (2 mm) pore sieve.

2.3 Microbiological Analysis of Soil Samples

2.3.1 Isolation, enumeration, characterisation and identification of isolates

Ten-fold serial dilutions of the soil samples were made according to standard procedures [9]. The first ten-fold dilution was made using 10 g of the soil samples in 90 mL of distilled water. The dilution was shaken and further serial ten-fold dilutions made up to 10^8. Aliquots(1.0 mL and 0.1 mL) of 10^{-4} to 10^{-6} dilutions of soil samples were cultured on nutrient agar, malt extract agar, sabouraud dextrose agar, nitrate agar, Winogradsky media (I and II), cellulose agar plates (Carboxymethyl cellulose- congo red agar) and phosphate solubilizing bacteria (PSB) medium (Pikovskaya's agar) plates using the spread and pour plate methods. The inoculated triplicate plates were incubated at 28 $\pm$ 2^{o}C for 18-24 hours for total heterotrophic bacteria, 2-7days for nitrifying, cellulolytic and phosphate solubilizing bacteria and 2-5 days for fungi. The emerging discrete colonies were counted using a colony counter and the bacteria/fungi population were expressed in colony forming unit per gram (CFU/g). Enumeration of the isolates was only in plates with colonies between 25 -250. The enumeration of specific bacterial groups (CB and PSB) was based on observation of clear zone around the bacterial colony and the population calculated per gram of soil.

The isolates were characterized and identified by comparing to known taxa using Bergey's Manual of Determinative Bacteriology [10]. Characterization and identification of fungal isolates were based mainly on their cultural and microscopic morphology and with the presence or absence of special reproductive structures [11,12].

2.3.2 Soil enzyme activities

The soil enzyme activities assessed included dehydrogenase and the phosphatases (acid and alkaline). Dehydrogenase activity was determined by the triphenyl tetrazolium chloride (TTC) method [13,14]. The evaluation of Phosphatase activity was based on the determination of p-nitrophenol released after incubation of soil with p-nitrophenyl phosphate [15]. All enzyme activity evaluation was performed in triplicates.

2.3.2.1 Determination of dehydrogenase activity in soils

The Triphenyl tetrazolium Chloride (TTC) method based on the estimation of TTC reduction rate to triphenyl formazan (TPF) in the soil after incubation was employed to determine dehydrogenase activity of the soil. Five grams of soil was weighed into test tubes and mixed with 5 mL of TTC (dissolved in Tris buffer) solution. The tubes were sealed with rubber stoppers and incubated for 24 hours at 30°C. The control containing only 5 mL of Tris-HCl buffer (i.e. Hydroxy-methyl-aminomethane in distilled water + HCl) without TTC was also prepared. After incubation, 40 mL acetone was added to each tube and shaken thoroughly and further incubated at room temperature for 2 hours in the dark, shaking the tubes at intervals. The soil suspension was then filtered and the optical density of the clear supernatant measured against the blank at 546 nm (red colour).

2.3.2.2 Determination of phosphatase (acid and alkaline) activity of soils

Phosphatase activity was determined using the method based on the determination of p-nitrophenol released after the incubation of soil with p-nitrophenyl phosphate. 1 g of soil sample was treated with 0.25 mL of toluene. 4ml of modified universal buffer (MUB) (pH of 6.5 and 11 was used for the assay of acid and alkaline phosphatase respectively) and 1 ml of p-nitrophenyl phosphate solution made in the buffer was mixed with the treated soil and incubated at 37°C for one hour. After incubation, 1 mL of $CaCl_2$ and 4 mL of NaOH was added and the mixture was filtered. The absorbance of suspension was done at 400 nm. Controls were

also performed with the addition of 1 ml of p-nitrophenyl phosphate solution after the addition of $CaCl_2$ and 4ml of NaOH immediately before filtration of the soil suspension.

2.4 Physicochemical Analysis

Physicochemical analysis of the soil was carried out according to standard procedures [16,17]. The Bouyoucos (Hydrometer) method was employed for particle size distribution analysis. The conductivity meter was used to measure the electrical conductivity and the pH was determined by the electrometric method in 1:1 soil/water ratio.

2.5 Statistical Analysis

Statistical package for the social sciences (SPSS) version 17.0 was employed for the statistical analysis of data generated. Mean, standard error of the mean, analysis of variance (ANOVA), least significant difference (LSD) and correlations were employed at 95% level of confidence.

3. RESULTS

3.1 Microbial Isolates of Coastal Wetland Soils

A total of 1,092 bacterial isolates belonging to 17 genera and 224 fungal isolates belonging to 6 genera were recovered from the wetland soils based on cultural, morphological and biochemical characteristics. The microorganisms associated with the coastal wetland soils included members of the genera *Acinetobacter, Alcaligenes, Arthrobacter, Azotobacter, Bacillus, Beijerinckia, Cellulomonas, Flavobacterium, Micrococcus, Nitrobacter, Nitrosomonas, Proteus, Pseudomonas, Rhizobium, Sarcina, Serratia and Staphylococcus.* The fungi belonged to the genera *Aspergillus, Cladosporium, Fusarium, Mucor, Penicillium* and *Rhizopus*.

3.2 Microbial Counts

The results of the total heterotrophic bacterial counts (THBC) and total fungal counts (TFC) from three soil depths (0 – 15 cm, 15 – 30 cm and 30 – 45 cm) of Ayadehe coastal wetland soils during the wet and dry seasons are as presented in Fig. 1. Highest microbial counts were observed for soils at 0 – 15 cm depth for all microbial groups in the wet and dry seasons respectively. The mean microbial counts of THBC and TFC ranged from 5.7 to 7.98 Log_{10} CFU g^{-1} which was 0.94 to 1.01 times higher in the wet season than a dry season and the difference significant at p=0.05.

Fig. 2 shows the nitrifying bacteria (NB), phosphate solubilizing bacteria (PSB) and cellulolytic bacteria (CB) counts obtained from three soil depths of Ayadehe coastal wetland soils during the wet and dry seasons. The microbial counts of these specific bacterial groups ranged from 0.0 to 5.6 Log_{10} CFU g^{-1}. However, the nitrifying bacterial counts were not obtained at 30 – 45 cm soil depth in both seasons.

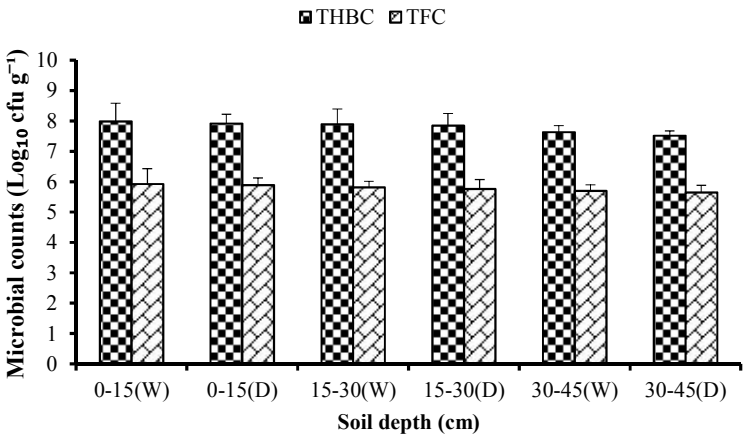

Fig. 1. Microbial counts of major microbial groups (total heterotrophic bacteria and fungi) associated with Ayadehe coastal wetland soil at three soil depths during the dry and wet seasons. Letters in bracket indicate the wet (W) and dry (D) seasons

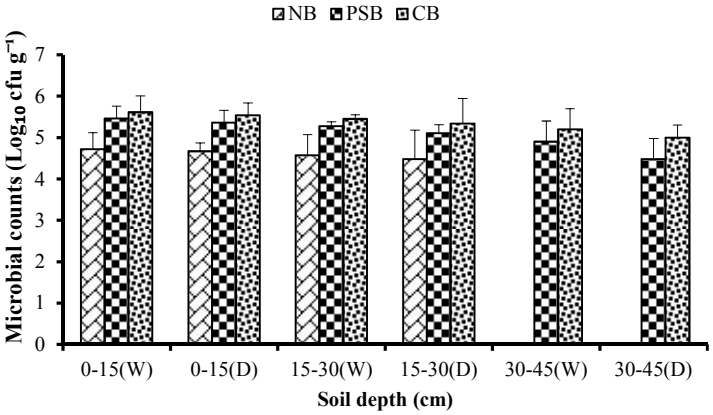

Fig. 2. Microbial counts of specific bacterial groups (nitrifying [NB], phosphate solubilizing [PSB] and cellulolytic bacteria [CB]) in the coastal wetland soil. Letters in parenthesis indicate the wet (W) and dry (D) seasons

3.3 Enzyme Activities of Soils

The Dehydrogenase activities of the soil in the wet and dry seasons are as presented in Figure 3. Dehydrogenase activity values ranged between 32.29 ± 0.05 and 53.51 ± 0.08 mg/g in the wet and dry seasons.

The activities of acid and alkaline phosphatases in the wet and dry seasons is presented in Fig. 4. Acid Phosphatase activity ranged between 0.71 ± 0.05 and 1.44 ± 0.03 mg/g, whereas a range of 0.87 ± 0.04 and 1.76 ± 0.2 mg/g of alkaline Phosphatase activity was recorded in the wet and dry seasons.

3.4 Physicochemical Characteristics

The physicochemical characterization of the wetland soils in the wet and dry seasons is presented in Table 1. The soil pH ranged between 6.0 ± 0.0 and 6.2 ± 0.01 in the wet and dry seasons. The electrical conductivity of the soils was 0.03 ±0.0 in the wet season and 0.04 ± 0.0 in the dry season. Particle size distribution indicated that the sand particle was dominant in the range of 64.8 ± 0.4% and 75.8 ± 0.05% in the wet and dry seasons.

4. DISCUSSION

Akwa Ibom State is endowed with abundant wetlands which provide areas where crude oil exploration and production activities are carried out with little or no crop production [6]. The microbial studies of Ayadehe coastal wetland soils revealed various genera of bacteria and fungi associated with the soil. The bacterial isolates included species of the genera *Acinetobacter, Alcaligenes,*

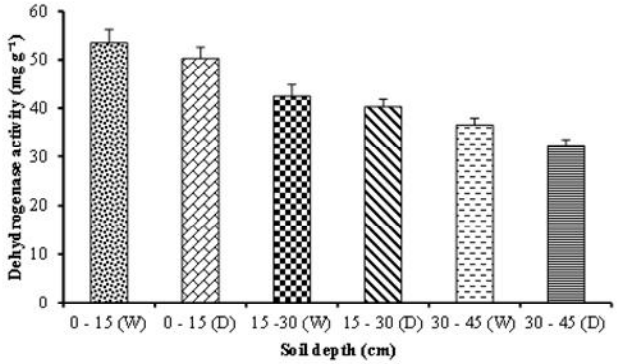

Fig. 3. Dehydrogenase activity of Ayadehe coastal wetland soil in the wet and dry seasons. Letters in parenthesis indicate the wet (W) and dry (D) seasons

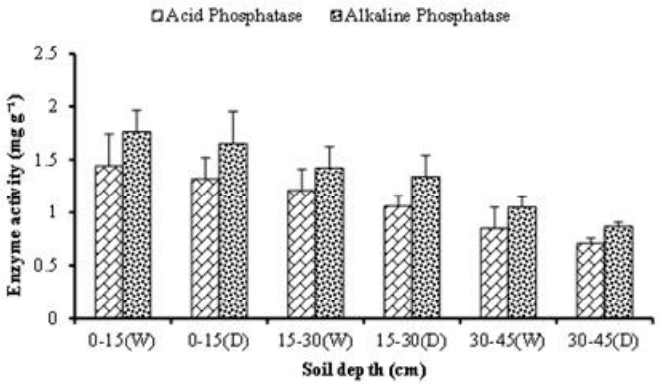

Fig. 4. Acid and alkaline phosphatase activities in Ayadehe coastal wetland soil. Letters in parenthesis indicate the wet (W) and dry (D) seasons

Table 1. Physicochemical characteristics of Ayadehe Coastal wetland soils

Season	Soil depth (cm)	pH	Electrical conductivity (ds/m)	Particle size distribution (%)		
				Sand	Clay	Silt
Wet	0 - 15	6.2± 0.01	0.03± 0.01	75.8 ±.0.05	15.6 ± 0.07	8.6 ± 0.02
Dry	0 - 15	6.0 ± 0.0	0.04 ± 0.0	76.8 ± 0.06	15.1 ± 0.03	8.8 ± 0.03
Wet	15 - 30	6.2± 0.04	0.03 ± 0.0	70.4 ± 0.02	20.6 ± 0.03	9.0 ± 0.04
Dry	15 - 30	6.0± 0.01	0.04 ± 0.0	73.6 ± 0.03	17.2 ± 0.02	9.2 ± 0.07
Wet	30 - 45	6.2 ± 0.0	0.03± 0.01	64.8 ± 0.4	25.5 ± 0.06	9.0 ± 0.05
Dry	30 - 45	6.0± 0.04	0.04 ± 0.0	64.9 ± 0.01	25.1 ± 0.07	10.0 ± 0.02

Values are the mean of triplicate determinations ± standard deviation

Arthrobacter, Azotobacter, Bacillus, Berjerinckia, Cellulomonas, Flavobacterium, Micrococcus, Nitrobacter, Nitrosomonas, Proteus, Pseudomonas, Rhizobium, Sarcina, Serratia and *Staphylococcus.* The fungi included species of the genera *Aspergillus, Cladosporium, Fusarium, Mucor, Penicillium* and *Rhizopus.* These microorganisms play critical roles in biodegradation, biogeochemical cycling, bioremediation and bio-control activities in the environment. The microorganisms associated with the coastal wetland soils are indigenous to soil and associated with soil organic matter [18,19,20].

Soil microorganisms play a critical role in the organic matter decomposition, stability of soil structure as well as mineral recycling. They play vital roles in the recycling of carbon, nitrogen, phosphorus, sulphur, manganese and iron [18,20,21]. Bacterial species of the genera *Bacillus, Arthrobacter, Flavobacterium, Pseudomonas, Micrococcus, Cellulomonas, Clostridium, Serratia* contribute immensely in the biodegradation of chitin, lignin, celluloses and hemicelluloses while fungi species of the genera *Penicillium, Aspergillus, Rhizopus* and *Fusarium* are involved in the degradation of plant materials [18,20,21,22].

Soil microorganisms involved in nitrogen fixation include bacterial species of the genera *Azotobacter, Beijerinckia*, *Bacillus* and *Pseudomonas* which are able to fix nitrogen in the soil. These organisms were isolated from the wetland soils in the wet and dry seasons. Nitrogen fixation by these microbes is accompanied by nitrogenase, ATP, reduced ferredoxin and other cytochromes and coenzymes. It occurs in surface and subsurface habitats. Nitrification which occurs extensively in aerobic habitats is performed mainly by autotrophic nitrifiers and a few heterotrophic fungi and bacteria. These include species of the genera *Nitrosomonas, Nitrobacter, Arthrobacter* and *Aspergillus*. Species of *Alcaligenes, Bacillus, Flavobacterium,* and *Staphylococcus* reduce nitrate to nitrite which under certain conditions is reduced via hydroxylamine to ammonium (nitrate ammonification) [18].

Transformation of phosphorus mediated by microbes can be viewed as a transfer of inorganic to organic phosphate or as transfer of phosphate from insoluble, immobilized forms to soluble or mobile compounds. Microorganisms reported to solubilize mineral phosphates and make them available to plants, including species of the genera *Bacillus, Alcaligenes, Arthrobacter, Flavobacterium, Micrococcus, Nitrosomonas, Nitrobacter, Pseudomonas, Serratia, Rhizobium, Mucor, Fusarium, Cladosporium, Aspergillus, Rhizopus* and *Penicillium* [18]. These microbes were isolated from the coastal wetland soils in the wet and dry seasons. A large heterogeneous group of heterotrophic bacteria which include *Bacillus, Pseudomonas, Proteus, Alcaligenes* are involved in iron reduction activities [20]. These were also isolated from the coastal wetland soils.

Manganese is also an essential trace element for plants, animals and many microorganisms. Microorganisms involved in the oxidation of manganese include species of the genera *Bacillus, Arthrobacter* and *Pseudomonas*. These microbes were also isolated from the coastal wetland soils during this study. The decomposing and mineral recycling activities of soil microbes enhance the fertility of soils and help in the mineralization of some complex compounds (e.g. toxic substances) that may be added to soils through diverse agricultural or industrial activities, thus preventing the toxic accumulation of such substances in soils [18,22].

Soil microorganisms have also been reported to be capable of producing auxins and Gibberellin – like organic chemicals that increase the rate of seed germination and development of root hairs that aid in plant growth. These include species of the genera *Arthrobacter* and *Pseudomonas* which can form associations with the roots of plants. Some soil microbes such as species of *Pseudomonas* produce siderophores and can thus be used as biocontrol agents to control *Pythium,* causing damping-off diseases in seedlings [18].

Soil microbes also play a key role in the breakdown of harmful substances into less toxic or non-toxic forms. Studies have reported species of the genera *Bacillus, Arthrobacter, Pseudomonas, Penicillium* and *Aspergillus* among others that possess excellent degradative abilities in the biodegradation of complex toxic substances such as crude oil in soils. These microorganisms have been reported to be involved in bioremediation process [23,24]. These microorganisms have also been isolated from the soils understudy in the wet and dry seasons.

Generally, the soils of Ayadehe coastal wetland revealed higher microbial counts in the wet season than the dry season for all groups of microorganisms at all sampling points. The low variation in the microbial counts of the various groups could be attributed to slight variations in the properties of the wetland soils due to factors such as climatic changes in both seasons. Climatic changes can bring about an increase in soil temperature in the dry season and a lower temperature in the wet seasons which in turn can affect the soil microorganisms in respect to their tolerance to soil temperature. The wet season which is associated with an increase in soil moisture due to water supply mainly from rainfall and dry season associated with high evaporation rates, in turn, brings about other changes in the properties of the coastal wetland soils which can be responsible for the slight changes in the soil microbial counts in both seasons. The higher bioload in the wet season could also be attributed to dilution effects; the rainwater (run-offs) dilutes the harsh conditions prevalent in the soil to more favourable conditions (e.g. increase organic matter, decreased acidity) in the wet season. A similar seasonal difference in microbial counts has been observed for soil microorganisms and wetland soil microbial population [4,5,6,21]. There was also a decrease in microbial counts with an increase in soil depth in both wet and dry seasons at all sampling points and this indicates favourable growth conditions such as nutrients and oxygen being more available at the surface soil than the deeper portions (subsurface) of the soils [18,21]. These results corroborate with other studies in which a similar trend for wetland soils have been reported [4,5,6].

Ayadehe coastal wetland soils revealed total heterotrophic microbial counts for major groups of microorganisms in the order THBCs >TFCs.The bacteria (THBC) was the highest number of microbial isolates obtained from all the sampling points in the wet and dry seasons. This could be attributed to the tolerance of the heterotrophic bacteria in the soil to wide variations of the soil properties which prevailed in the wetland soils in both seasons. The occurrence of the heterotrophic bacteria in these wetland soils followed the same trend as reported for soil bacterial population and

wetland soils in Akwa Ibom State, Nigeria [4,5,6,20,21,22].

Fungi (TFC) constituted the second highest number of the major groups of soil microorganisms that inhabit the coastal wetland soils at all sampling points, and directly correlate with the mildly acidic nature of these soils in both seasons. Generally, the acidic environment supports the growth of fungi [21]. The specific groups of microorganisms, however, revealed microbial counts in the order; CB>PSB >NB, in the wet and dry seasons at all sampling points. The variations in tolerance of the prevalent conditions at the coastal wetlands by specific groups of microorganisms could have contributed to the cellulolytic and nitrifying bacteria constituting the highest and least numbers respectively in the wet and dry seasons. Major NB was not isolated from soils of depth beyond 30 cm at all sampling points in the wet and dry seasons. The non-recovery of the nitrifying bacteria beyond the depth of 30 cm in part can be attributed to their strict aerobic nature and available oxygen which decreases with increase in soil depth [18,21] and in part, the detection limit of the culture-dependent approach used in the study.

Statistically, there exist significant difference ($p = 0.05$) among the microbial groups in the wet and dry seasons and with soil depth. The LSD test among microbial groups also revealed that CB and THBC, NB and THBC, PSB and THBC as well as TFC and THBC were significantly different pairs ($p = 0.05$). Enzyme activities play a key role in the biochemical functioning of soils, including soil organic matter formation and degradation, nutrient recycling and decomposition of xenobiotics. These activities arise from the presence of different types of enzymes present in soil and within soil microorganisms. It can directly reflect the biological situation in the soils [24,25,26]. Dehydrogenases are intercellular enzymes that catalyze oxidation-reduction reactions required for the transformation of organic compounds. These enzymes are inactive when present outside a cell and are considered a measure of microbial activity [18]. Dehydrogenase activities (DH) of the coastal wetland soils revealed highest values (53.51 ± 0.08 and 50.34 ± 0.03 mg g h^{-1}) in the wet and dry seasons respectively at 0 - 15 cm soil depth. Correlations revealed a strong positive linear relationship between dehydrogenase activity and microbial densities in soils during the wet ($r = 0.84$) and dry ($r = 0.81$) seasons.

Phosphatases are membrane-bound enzymes whose activities determine the number of membrane properties, both structural and functional. Soil phosphatases play a major role in the mineralization process of organic phosphorus substrates. The activity of acid phosphatase is optimum in an acidic medium, while alkaline phosphatase activity is supported by alkaline medium [18,27]. Activities of phosphatases (Ac.P and Al.P) in the wetland soils was higher in the wet season than dry season at all assessed soil depths. There was, however, no statistically significant difference ($p = 0.05$) in the activities of the phosphatases but only slight variations in both seasons. Generally, the interactions between the enzyme activities (DH and Ac.P and Al.P activities) and seasons, as well as phosphatase activities and soil depths, did not show any significant difference ($p = 0.05$) for seasons and soil depths respectively.

The particle size distribution of the coastal wetland soils revealed dominant high sand fraction with deposits of clay and considerable quantities of silt in both wet and dry seasons. There was a decrease in sand fractions of the soils at various points with an increase in soil depth, while the clay fraction increased with soil depth at all sampling points in both seasons. The textural class revealed sandy clay loam [19] and the observation correlates with reports for wetland soils of southern Nigeria [2,3,7,28, 29,30,31]. Statistically, there was no significant difference in the particle size distribution among sampling points and seasons at the different wetland sites. The soil texture plays a key role in carbon storage and strongly influences nutrient retention and availability. It represents one of the most important factors influencing the structure of microbial communities as well as pH, cation exchange capacity moisture and organic matter content. It is a very important property for the ecology of microorganisms since it describes the surface area that is available as a habitat for the growth of microbes [32,33]. The texture of the coastal wetland soils was such that can provide a good rooting environment for crops and was well drained for good aeration and the growth of microorganisms. The high percentage of sand in the wetland soils understudy could be attributed to the nature/type of parent material which influences the characteristics of wetland soils of southern Nigeria [3,30].

Soil pH influence nutrient adsorption and plant growth through the direct effect of the hydrogen ion or indirectly on nutrient availability and the presence of toxic ions. Very high pH tend to reduce the availability of some micronutrients to plants and very low pH (i.e. highly acidic) results in the solubility of sufficient quantities to be toxic to the growth of some plant. The activities of bacteria are reduced at very low soil pH, while at a very low pH fungal activities are encouraged. However, at intermediate pH ranges, the bacteria have a competitive advantage over the fungi. Major processes such as nitrification and nitrogen fixation take place vigorously at a pH of 5.5 and above [18,22]. The results of this study indicate the coastal wetland soils to be acidic with a pH range of 6.0 ± 0.0 to 6.2 ± 0.04 in the wet and dry seasons. The mildly acidic nature correlates with reports of soil pH for Akwa Ibom State and southeastern Nigeria wetlands. This could be attributed to the climate and acid parent material [2,3,7,28,34]. Further to these findings, pH values for the coastal wetland soils fall into the range that favour the growth of most crops and microbial activities.

Electrical conductivity (EC) indicates total quantities of soluble salts in soils. The quantities of salt which pass into solution depend on the relative amounts of soil and water used, although the relationship is variable. Electrical conductivity increases with an increase in evapotranspiration and a reduction in the amount of rainfall [22]. Salt affects crop germination and density, as also vegetation development, reducing productivity and in most serious cases, leading to generalized plant death, limiting nutrient adsorption and reducing the quality of the available water. Elevated salinity weakens plants due to the increase in osmotic pressure and the toxic effect of the salts. In addition, salinization affects the metabolism of the organisms present in the soil, drastically reducing soil fertility and increasing waterproofing of the deeper layers, impeding cultivation of the land. In an indirect way, soil salinization can adversely affect plant growth, due to the destruction of the soil structure [35]. Soils with EC values of 0 – 4 ds m^{-1} are considered non-saline soils and plants grown on these soils have no salinity concerns [15]. The EC values of the coastal wetland soils ranged between 0.03 (± 0.0) and 0.04 (± 0.0) ds m^{-1} which indicate that these wetland soils do not have salinity problem. However, EC of the coastal wetland soils was slightly higher in the dry season than the wet season at all sampling points and this could be attributed to reduced precipitation during the dry season at the coastal region.

5. CONCLUSION

In Akwa Ibom State where wetlands are extensive, large portions of this important land mass lie waste.The results of this study indicate Ayadehe coastal wetland soils suitability for land utilization to include agricultural practices in order to boost food production. The physical characteristics of the wetland soils under present study indicate planting on the flat or in holes (minimum or zero tillage), contour tillage, strip cropping and terracing as agricultural practices that can help preserve the soil structure and also prevent or control erosion along sloping fields of the wetland. The favourable pH of the wetland soils indicates the growth of tree crops such as coconut, oil palm and rubber which tolerate acidic conditions on the wetland. Arable cultivation of crops such as rice, cassava, sweet potato, maize and vegetables should also be employed on these wetland soils. The presence of diverse enzymes and the rich assemblage of microorganisms to carry out critical ecosystem services indicates the potential to support crop production.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Jacob JS, Moulton DW, Lopez RA. Texas coastal wetlands guidebook. Texas Sea Grant Publication, Texas; 2003.
2. Udoh BT, Ibia TO, Udo BU, Edem SO. Assessment of micro-nutrient status of inland depression and flood plain (Wetland). Soils in Akwa Ibom State South – Eastern Nigeria. Journal of Tropical Agriculture, Food, Environment and Extension. 2008;7(2):156–161.
3. Ogban PI, Effiong GS, Obi JC, Ibia TO. Characteristics, potential and constraints of wetland soils for agricultural development in Akwa Ibom State, South Eastern Nigeria. Nigerian Journal of Agriculture, Food and Environment. 2011;7(2):80–87.
4. Udotong IR, Akpanekon OJ. Micro-biological and physicochemical studies of inland wetland soils in Ikot Ekpene,

Nigeria. Nigerian Journal of Microbiology. 2007a;21:1523–1534.
5. Udotong IR, Akpanekon OJ. Micro-biological and physicochemical studies of wetland soils in Itu, Nigeria. Nigerian Journal of Microbiology. 2007b;21:1598–1610.
6. Udotong IR, John OUM, Udotong JIR. Microbiological and physicochemical studies of wetland soils in Eket, Nigeria. World Academy of Science, Engineering and Technology. 2008;20:837–842.
7. Ahukaemere CM, Eshett ET, Ahiwe C. Characterization and fertility status of wetlands in Abia state Agro-ecological zone of southeastern Nigeria. Nigerian Journal of Soil Science. 2014;24(1):147-157.
8. Umoh GS. Programming risks in wetland farming: Evidence from Nigerian flood plain. Journal of Human Ecology. 2008; 24(2):85–92.
9. Etok CA, Udo SM, Eja ME. General microbiology practical manual. Abison Printing Press, Calabar, Nigeria; 2004.
10. Holt JG, Kreig NR, Sneath PHA, Staley JT, Williams ST. Bergey's manual of determinative bacteriology (9th Edition) Williams and Wilkins Publishers, Baltimore, USA; 1994.
11. Barnett HL, Hunter BB. Illustrated genera of imperfect fungi. Macmillan Publishing Company USA; 2000.
12. Efivuwevwere BJO. Microbial spoilage agents of tropical and assorted fruits and vegetables. An Illustrated Reference Book Port Harcourt, Nigeria: Para Graphics; 2000.
13. Nwaugo VO, Onyeagba RA, Azu N, Nworie O. Petroleum produced (Formation) water induced changes in bacterial quality and soil enzymatic activities in a farmland in Egbema, Southern, Nigeria. Estud. Biol. 2007;66: 89–97.
14. Alef K. Dehydrogenase activity. In: Alef K, Nannipieri P. editors. Methods in soil microbiology and biochemistry. Academic Press Ltd. 1995;228-231.
15. Alef K, Nannipieri P, Trazar-cepeda C. Phosphatase activity. In: Alef K, Nannipieri P. editors. Methods in soil microbiology and biochemistry. Academic Press Ltd. 1995;335-339.
16. Udo EJ, Ibia TO, Ogunwale JA, Ano AO, Esu IE. Manual of soil, plant and water analysis. Sibon Books Limited, Lagos; 2009.
17. Association of official analytical chemists (AOAC) official methods of analysis (19th Edition) AOAC. Washington DC; 2012.
18. Mohapatra PK. Textbook of environmental microbiology. I. K. International Publishing House Pvt. Limited, New Delhi. 2008;128–484.
19. Wiley JM, Sherwood LM, Woolverton CJ. Prescott, Harley and Kleins Microbiology (7th Edition) McGraw – Hill Education, New York. 2008;132–147.
20. Hoorman JJ. The role of soil bacteria. In: Fact sheet agriculture and natural resources. The Ohio State University Extension. 2011;1–4.
21. AGRIINFO. In soil microbiology. In: My Agriculture Information Book; 2011. (Accessed on 11th December, 2012) Available:http://Agriinfo.In
22. Brady NC, Weil RR. The nature and properties of soils (14th Edition) Prentice Hall, New Jersey; 2008.
23. Soares FL (Jr.), Mello JS, Dias AC, Andreote FD. Cellulolytic bacteria from soils in harsh environments. World Journal of Microbiology and Biotechnology. 2012; 28(5):21950–21203.
24. Das N, Chandran P. Microbial degradation of petroleum hydrocarbon contaminants: An overview: Biotechnology Research International. 2011;1–13.
25. Acosta-Martinez V, Cruz L, Sotomayor-Ramirez D, Perez-Alegria L. Enzyme activities as affected by soil properties and land use in tropical watershed. Applied Soil Energy. 2007;35:35–45.
26. Sobolev D, Begonia MFT. Effects of heavy metal contamination upon soil microbes: Lead-induced changes in general and denitrifying microbial communities as evidenced by molecular markers. International Journal of Environmental Research and Public Health. 2008;5(5): 450–456.
27. Bahrampour T, Moghanlo VS. Evaluation of soil biological activity after soil contamination by crude oil. International Journal of Agriculture Research and Review. 2012;2(6):671-679.
28. Effiong GS, Ibia TO. Characteristics and constraints of some river flood plain soils to crop production in south-eastern Nigeria. Medwell Agricultural Journal. 2009;4(2): 103–108.

29. Chukwu GO, Chude LA, Ekpo IE. Wetland of south-eastern Nigeria; extent and characteristics. Nigerian Journal of Agriculture, Food and Environment. 2009; 5(2–4):42–46.
30. Ogban PI, Babalola O. Characteristics, classification and management of inland valley bottom soils for crop production in sub-humid south western Nigeria. Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension. 2009; 8(1):1–13.
31. Babalola TS, Oso T, Fasina AS, Godon K. Land evaluation studies of two wetland soils in Nigeria. International Research Journal of Agricultural Science and Soil Science. 2011;1(6):671–679.
32. Harmarashid NK, Othman MA, Hussain MH. Effects of soil texture on chemical compositions, microbial populations and carbon mineralization in soil. Egypt Journal of Experimental Biology. 2010;6(1):59–64.
33. Chau JF, Bagtzoglou AC, Willig MR. The effects of soil texture on richness and diversity of bacterial communities. Experimental Forensics. 2011;12:33–341.
34. Imogie AE, Udosen CV, Ailede CI, Enonuya DOM. Utilization of Niger Delta basin coastal fresh water swamps for meaningful agricultural production. Greener Journal of Agricultural Sciences. 2012;2(5):180–187.
35. Silva CMMS, Fray EF. Effect of salinity on soil microorganisms. In: Soil health and land use management. Soriano MCH. (Ed.); 2012.
(Accessed on 7th November, 2013)
Available:Www.Intechopen.Com/Books/Soil-Health-AndLand-Use-Management/
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