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Physicochemical and Microbial Properties of eroded coastal soil in Eagle Island Rivers State, Nigeria

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Abstract

Coastal areas around the world are quickly eroding because of uncontrolled deforestation. Thus, this study aimed to determine the chemical concentration and microbial population of soils on eroded shorelines at three levels (i.e., top, medium, and bottom). The soil sample was sent to the laboratory for physicochemical analyses of cadmium, lead, and total hydrocarbon content. The results revealed that the mean THC of top, middle, and bottom soil were 1.31±0.07 mg/kg, 0.77±0.03 mg/kg, and 0.3±0.02 mg/kg while the control was 0.01±0.01 mg/kg. Also, the mean cadmium (Cd) and lead (Pb) levels were statistically similar at p>0.05 in values (i.e. 0.001±0.001mg/kg) when compared to the control. The population of total heterotrophic bacteria (THB) and total heterotrophic fungi of the control were 1.7cfu/g and 1.1cfu/g, respectively. The population of THB and THF in root soil were 2.3cfu/g and 0.9cfu/g, respectively. Also, the populations of THB and THF in the root were 2.9cfu/g and 1.4cfu/g, respectively. The mean THC level of the top soil was significantly highest, followed by that of the middle and bottom, while the least was the control. The significantly increased THC levels observed in the top, middle, and bottom soil in comparison to the control is as a result of deposition of hydrocarbon wastes by anthropogenic activities. The THB estimated in mangrove roots was significantly highest in lead concentration, followed by root soil, while the control was the least. The THB in root and soil-root samples was significantly higher than in the control. The significantly increased THB population observed in the mangrove and soil roots suggests possible increases in anthropogenic activities, which might have triggered favorable bacterial growth conditions. Therefore, the result implies that deforested areas can be a metal sink and a source of contaminants to the nearby mangrove vegetation, which may, in turn, move to humans through the food chain.

Keywords: *Microbes, biotic system, cadmium, lead, heterotrophic bacteria and soil*

1.0. INTRODUCTION

Tidal erosion has negative effect in many countries worldwide, including Nigeria. An extremely braided river erodes banks in its entire course by increasing its area and forming and destroying sand bars or chars, causing vast amounts of sediment. At present, tidal erosion is the major natural hazard for the riverside people, which has attracted attention from countries globally [1]. Tidal erosion causes multidimensional, ecological and environmental impacts Tidal erosion leads to the loss of crops, fertile land and other land-based resources. In addition, flooding displaces microbes and destroys the physico-chemical properties of the soil, which in turn is inimical to agricultural growth. [2].

The physicochemical properties and the structure and composition of the soil play key role in preventing tidal erosion. Soil chemistry influences the activities of microorganisms, which in turn play vital role in soil fertility and agricultural development in an agrarian society [3]. Similarly, the proliferation of microorganisms is dependent on the bulk density and soil porosity which is destroyed by erosion [4]. Increase in microbial activities helps in the sustenance of the soil and ensures an increase in productivity. Soil that is reinforced with rich humus soil and roots materials can withstand wind and water erosions [5]. Compaction negatively affect the function and structure of the soil and destroy the microbial population and prevent nutrient flow from the soil to roots of plants [6]. It is thus, important to determine the physico-chemical properties of the soil so as to know the impact of tidal erosion [7].

Tidal erosion has colossal impact on soil fertility and the microbial population [8], but not much have been studied in the Niger Delta region. The ecosystem comprises of the biotic system, which is made up of plants animals and microbes, but not much emphasis is given to the microbial community, which has made this work more necessary. The microbiota are the engine room of the coastal environment because of the increase in organic waste, which has necessitated the actions of decomposers. The trophic dynamic of the coastal community is regulated by the activities of decomposers which drives the energy within and outside the coastal areas. Stochastic changes in the coastal environment increases the unpredictability of natural events, which are worsened by adverse anthropogenic activities [9].

Microbes play role in gaseous exchange and nutrient cycle in terrestrial, aquatic and atmospheric environments [9]. The mangrove forest and its adjoining water bodies provide a conducive environment for microbial activity, which helps the circulation of nutrients [10] in a web of trophic activities. Since mangrove forest is a haven for multiple species decomposition activity is a vital source of energy. Therefore, the washing away of the soil creates a dislocation that destabilizes ecosystem function.

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The soil physico-chemical property facilitates or impedes the biotic processes of the soil. Litter fall from mangrove trees provide the raw materials for decomposers to break down organic materials to fertilize the soil. Coastal erosion can also add or remove nutrients from the soil

Tidal erosion, which is the wearing a way of coastal soil [12] is a problem in many coastal communities because of human-mediated activities of deforestation and sand removal for piling buildings constructed on wetlands. Locals dig up chikoko soil and use it to reinforce the buildings they erect on the swamp. Scooping up soil fragments makes it vulnerable to tidal erosion, which further accretes the soil and washes away microbes and other soil-dwelling organisms. In the same vein, the number of trees in mangroves forest has declined drastically over the years because of firewood production and urban renewal project for the construction of houses. Flooding from high volume of water from terrestrial area add to the erosional process by creating a wetland depleted of nutrients and microbes. The shape of the land also add to the severity of the flooding, sloppy areas leads to high acceleration of run-off water which washes the soil and deposits it in the river as sediments. The soft nature of the soil makes it wash faster compared to rocky soil. The Niger Delta soil is derived from sedimentary rock that is soft alluvial; hus, it erodes easily by tides.

During the rainfall season erosion intensifies because the accumulation of upland water drains into the river [13] while during high tide the river water overflows and washes away the edges of the shore line. The topography of the study area Eagle Island, which has low elevation help to accelerate erosional processes. But before the forest is removed, the mangrove trees help to break up and stop the erosion force and reduce the speed of the incoming water. While the tree roots hold the soil together to prevent both wind and water erosion from washing the soil particles.

The microbial community make up the decomposers, which in turn include fungi, protest, bacteria and earthworms. At the study site the fungal group include molds and mushrooms and they grow and break down the remains of dead plant and animal matter. On the other hand decomposers are microscopic decomposers that cause decay [14]. Bacteria and fungi break down dead organic matter in the soil. Ground dwelling organisms such as earthworms and fiddler crabs (*Uca tenageri*) bore holes and create burrows. Which help to aerate the soil and increases its fertility for plant growth [15], which has made the wetland to be a biodiversity hotspot [15]. But erosion destroys and wipes out the organisms and removes their ecosystem services. The breaking away of the soil hill by tidal force creates a sandy coastal plan whose physicochemistry is different from the usual muddy soil known as “chikoko”[16].

The nature of the soil and water content determine the extent of erosion. Lose soil will move faster and easily carried by tidal force. The river picks up and move particles and pebbles along the way, which causes abrasion of the river bottom [17] leading to sediment formation that smother benthic and terrestrial organisms. The destabilization of the pedology leads to the dysfunction in the productivity of the coastal community. Thus, anthropogenic activities in and around the coastal environment complicate and blurs the ecosystem function and impairs microbial activity that makes the area bubble with life, after some years if the erosion continues the area may become barren and replete of vegetation [18].

Since soil and plants play major roles in carbon sequestration the destruction of the microbial population trough erosion will have a ripple effect on the survival of the ecosystem [19].

The specific objectives of the study include:

I. To determine the heavy metal concentration of tidally eroded soils

ii. To determine the microbial population of tidally eroded soils

iii. To measure the height of the eroded coastal shorelines.

2.0. MATERIALS AND METHODS

2.1. Description of study area

Eagle's Island is situated close to the Rivers State University of Science and Technology, Nigeria. It lies between (4.75N and 7.01E). The mean monthly temperature ranges from 28 to 34°C. The Island is characterized by low-lying terrain with low elevation of less than 5 meters above sea level. It experiences a tropical monsoon climate with high humidity and significant rainfall, especially during the wet season [21]. Dominated by mangrove forests and patches of freshwater swamp forests, Eagle's Island supports a variety of flora and fauna. The extensive swamp covers a large portion of land with a top layer of mud slurry overlying a relatively hard substratum. The soil is chocolate brown, and it is characterized by burrows made by fiddler crabs (*Uca tangeri*). Several species of plant are found in this area, such as the red mangroves (Rhizophoraracemosa), black mangroves (*Laguncularia racemosa*), white mangroves (*Avicennia germinans*), Nypa palm (*Nypa fruticians*) and grasses, e.g., *Mariscus longibracteatus* [16]. In the area, there is a river used for transportation.

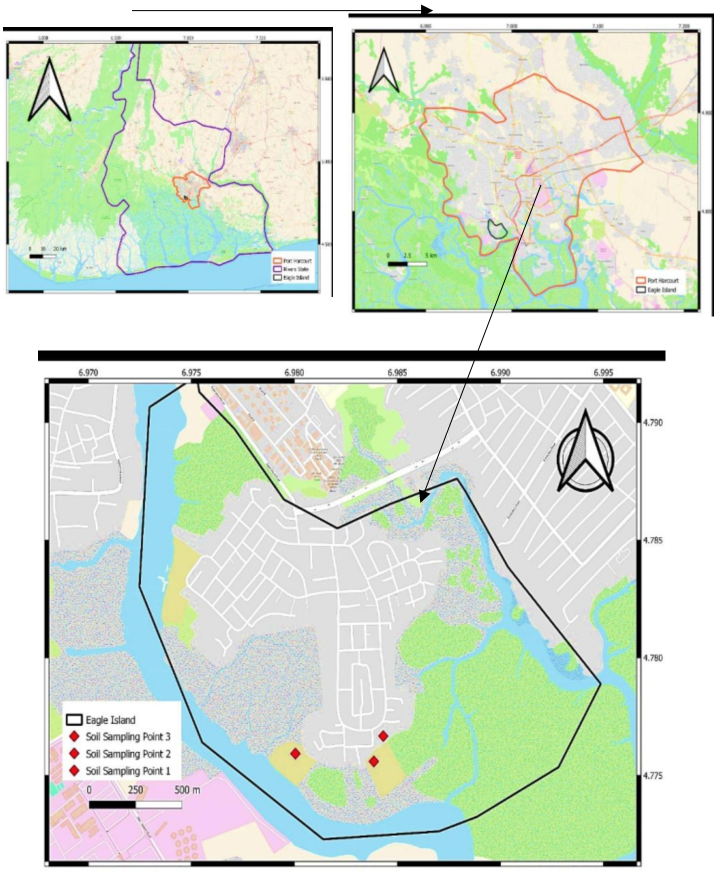

Figure 1. Map showing the study area at Eagle Island, Port Harcourt, Rivers State, Nigeria.
(Source: Geography Department University of Port Harcourt)

Figure 2. Eroded area in Eagle Island, River State, Nigeria.

2.2. Sample collection

A hand-held soil auger was used to collect soil samples at random from the top. Middle and bottom of the shore line as shown in Figure 2. The GPS coordinates were recorded correctly, and each sample was put in a well-labeled polythene bag for easy identification. It was kept in an ice-packed cooler below 4°C and later sent to the laboratory for further analysis. Water samples were collected from the sampling site using calibrated jars 0.5 meters below the water surface and sent to the lab for analysis [16].

Figure 3. Picture showing sample collection at Eagle Island, River State, Nigeria.

2.3. Laboratory analysis

2.3.1. Determination of Total Hydrocarbons (THC) Concentrations

A spectrophotometer was used to determine the total hydrocarbon using a calorimeter (i.e., HACH DR, 890). Two gram (2g) of the soil sample was measured and allowed to air dry before crushing as reported in [22]. After crushing, the soil sample was transferred into a glass extraction beaker, and 20ml of hexane was added to it and stirred. later on, the mixture was filtered through a glass funnel with wool, silica gel, and anhydrous sodium sulfate. 10ml of the organic extract was added to a 10ml sample curve before being transferred to the calorimeter. The detection limit for THC is 0.01mg/1 [23].

2.3.2. Heavy metal analysis.

Heavy metals were extracted following the procedures of [24]. 2g of sample was air dried and weighed into a clean extraction container. 20 ml of extraction solvent (Hexane) was added to the sample, mixed thoroughly, and allowed to settle. The mixture was carefully filtered into solvent-rinsed extraction bottles using filter paper fitted into Buchner funnels. The extracts were concentrated to 2 ml and then transferred for further processes.

2.3.3. Microbial Analysis

(i) Total heterotrophic bacteria (THB)

Under antiseptic conditions, 1g of soil was weighed and added into 9 ml sterile diluents (0.85% NaCl). The soil sample was shaken vigorously to homogenize and afterward serially diluted as reported by [24]. 0.1ml aliquot of the inoculum is collected using a sterile pipette and inoculated on the surface of Nutrient Agar (NA). The inoculum was spread equally with a sterile hockey stick and the plates were incubated at 37°C for 24 hours. The colony forming units (cfu) value per ml of the soil sample was determined by counting the colonies on the plates. Pure cultures were obtained on streaking distinct colonies on freshly prepared nutrient agar after 24 hours of incubation at 37°C. The pure culture was gram-stained and further sent for microscopic examination.

(ii) Total heterotrophic fungi (THF)

One gram (1g) od soil was similarly collected under aseptic conditions weighed and added into 9ml sterile diluents (0.85% NaCl). The combination was further shaken vigorously and serially diluted using a sterile pipette. 0.1ml aliquot of inoculum was inoculated on Sabouraud Dextrose Agar (SDA) acidified with 0.1% lactic acid to inhibit the growth of bacteria and allow for only the growth of fungi. Inoculated plates were incubated at ambient temperature for 3-5 days. The cultural characteristics were observed and subcultured for purification. The culture stained with lactophenol cotton blue was observed under a microscope at ×400 magnification.

2.4. Measurement of height of eroded shoreline

The height of the eroded shore line (Figure 2) was measured from the river bottom to the top and shows the measurements as follows height (1.75) m, middle (1.4 m) and top (1.35 m) (Figure 4). It shows that the height of the eroded shore decreases from the bottom to the top of the ground surface.

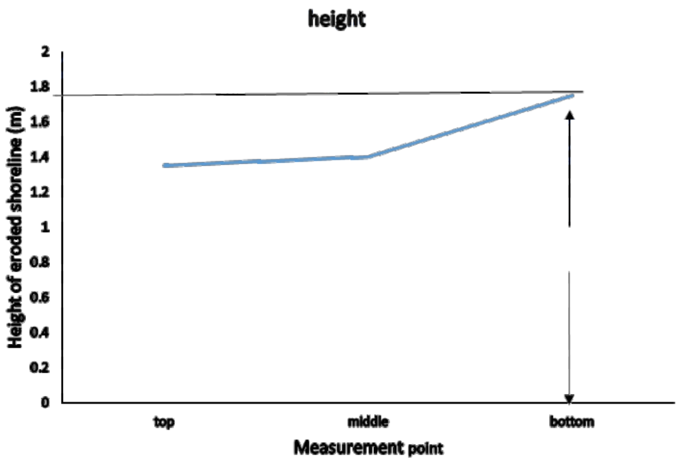

Figure 4. Line graph showing trend of eroded shoreline at Eagle Island, Rivers State, Nigeria.

2.5. Statistical Analysis

An analysis of variance (ANOVA) was conducted since there were multiple samples collected per block to test the significant difference in the concentration of hydrocarbon and heavy metals in water, soil, plant and animal samples collected within study plots. Logarithmic transformation of the data wasdone to meet assumptions of normality and homoscedasticity [25]. Similarly, a post-hoc Tukey's HSD test was done to test the pair wise mean differences between groups. All analyses were carried out in R statistical environment, 3.0.1 [26]).

3.0. RESULTS

3.1. Concentration of THC and heavy metals in tidal erosion sites

The concentration of THC decreased from top to bottom of the shore line and control soils (Figure 1), while the concentration of cadmium and lead was not significantly different in each eroded site ($F_{4,34}$= 1.09, $P > 0.05$, Table 1, Figure 1).

Table 1. The mean concentration of THC and heavy metals in eroded shore sites at Eagle Island, River State, Nigeria (n=3)

Soil site	Cadmium (mg/kg)	Lead (mg/kg)	THC
Top	0.001±0.001 ^{a}	0.001±0.001 ^{a}	1.31±0.07^{d}
Middle	0.001±0.001 ^{a}	0.001±0.001 ^{a}	0.77±0.03^{c}
Bottom	0.001±0.001 ^{a}	0.001±0.001 ^{a}	0.30±0.02^{b}
Control	0.001±0.001^{a}	0.001±0.001 ^{a}	0.01±0.01^{a}

Values are reported in mean and standard error of mean (M±SEM) (n=3). Values with similar superscripts $^{'a'}$ were not significantly different at a p-value of 0.05 from the controlwhile values having different superscripts were significantly different at p-value of 0.05.

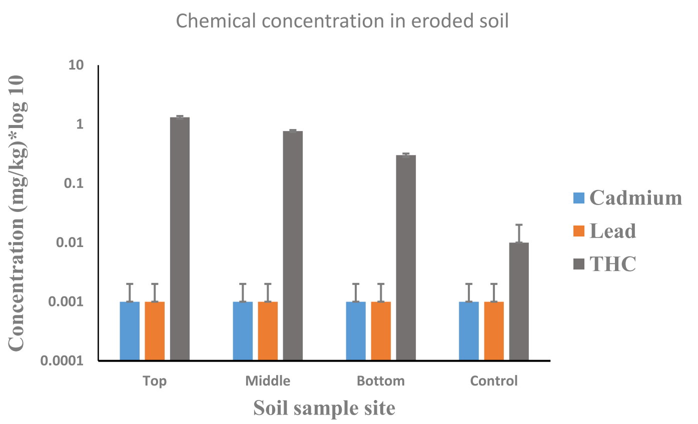

Figure 5. Mean chemical concentration in different soils in eroded shoreline at Eagle Island, River State, Nigeria (±SE).

3.1. Microbial population on the root and soil of mangrove tree

Figure 6. Shows the microbial population of sample collected from grey mangrove root and soil close to the root at Eagle Island.. There is no significant difference between the microbial population in the control, root and soil of the study area ($P > 0.05$).. But there was significant difference between the bacterial and fungal populations ($P < 0.05$). It shows that the bacterial population is larger than the fungal population. The mangrove root has higher bacterial population compared to the root soil and control soil. Similarly, the fungal population in the root is higher than the root soil and control soil (Figure 6).

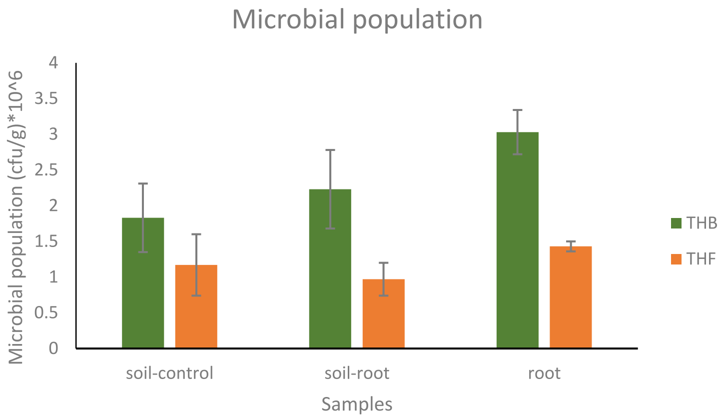

Figure 6. Mean microbial population in samples collected from soil and grey mangrove root at Eagle Island, Rivers State Nigeria (±SE).

4.0. DISCUSSION

There was no difference in heavy metal concentration across the three different points on the eroded shoreline (Table 1) because the washing of the soil by tidal force was done equally across the shoreline [27]. However, there was a difference in the concentration of the total hydrocarbon content across the sites because of the variability in hydrocarbon distribution in the soil. The top soil has higher concentration followed by the middle and the bottom because of the direct deposition of spilled crude oil and used diesel on the top surface. Furthermore, slow percolation of oil within the soil is as a result of the high plasticity of the soil which prevents aggressive oil percolation into the sub-surface. The control site also exhibited least concentration of THC compared to the eroded site because it was less disturbed by tidal erosion. Thus, erosion exposes the inner soil surface to the impact of anthropogenic activity on the ground surface, which implies that erosion apart from destabilizing and fragmenting the soil structure also influence the soil chemistry, which in turn affect the soil microbiology. Soil depleted of microbes have larger implication on the productivity and ecosystem services of the mangrove forest.

Bacteria is ubiquitous in the environment hence its greater population compared to fungi. The higher occurrence of microbes on the plant root is because they are decomposers of organic materials. Microbes have higher affinity for organic materials than the soil that is why they have fewer population on the soil that is far away from the mangrove tree (i.e., control soil) [27]. The presence of vegetation in the coastal environment helps the proliferation of microbial activity. Thus the natural processes of erosion and flooding and the deliberate deforestation of vegetation by humans have negative effect on the coastal environment [28]. Erosion has wider implication for man's survival when ground-dwelling organisms such as shell fish (e.g., periwinkle and mussel) and crabs are lost through erosive action.

Loss of vegetation also aggravate global warming due to the loss of carbon sequestration ability of the forest. The soil is one of the earth's most valuable resources because almost everything depends on it directly or indirectly for survival. To save the forest soil from further destruction by erosion an aggressive afforestation program should be embarked upon to help maintain the soil stability.

The study site is a deforested area and open to the effects of tidal erosion and human-mediated activities (fishing, sand mining, and waste disposal). There is continuous wearing away of the swampy soil due to tidal activities, which deposit plastic and different waste types at the study site [29].

5.0. CONCLUSION

The study showed that erosion has both physical, chemical and microbial impact on coastal soil. A major causative factor is deforestation. The presence of vegetation helps to hold the soil together to prevent the impact of tidal force. Thus, the continuous depletion of the soil leads to the loss of ground dwelling organism (e.g. fiddler crabs) that are of economic importance to humans. Similarly, loss of vegetation leads to increase in the impact of climate change. This is because the mangrove forest serve as a major carbon sequestration agency. Its loss will be a global loss because the earth is a global village that once a region is impacted it will have ripple effect on other parts of the world [30].

6.0. RECOMMENDATION

1. Biomonitoring programs should be set up to regularly assess the physicochemical and microbial properties of the soil and ground-dwelling organisms, such as periwinkles consumed by people in Eagles Island, to prevent adverse effects on human health. Periodic analysis would track changes over time and help identify new sources of contamination or degradation.
2. Public awareness programs should be carried out for the local community and stakeholders on the importance of sustainable land use to protect soil health and biodiversity.
3. Environmental agencies should enact environmental laws to control pollution levels and ensure that activities on Eagles Island comply with environmental standards.

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