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Research Article

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Soil and Water Microbiological Characteristics of Olo Flowstation and Rumuekpe Metering Station, Rivers State, Nigeria

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Abstract

This study evaluates the soil and microbiological properties of Olo Flowstation and Rumuekpe Metering Station. Standard sampling and analytical methods were adopted. Results of the soil microbiological composite samples from the random samples showed that the percent Hydrocarbon Utilizing Bacteria (HUB) was 40.0% and 27.27% for the top and subsoil, respectively. Though these values were high, they were below expected values in view of the high level of petroleum hydrocarbon spilled on the soils collected. The moderately high amount of hydrocarbon degraders in these soils compared to the control indicated that these soils might have been in contact with petroleum products which might have polluted the soils. The poor drainage resulting from stagnant water might have leached the petroleum products down the soil along transect, resulting into higher HUB% in the subsoil than the top soil. Other sampling stations had better top soil drainage hence lower % HUB down the profile. All the water samples, both surface and groundwater showed significant range of bacteria. The colonies were within 30 to 300. The growth for bacteria ranges from 1.5×10^5 cfu/ml at Elele-Alimini (up-stream) to 3.0×10^5 cfu/ml at the waste pit, Sombreiro River and flare pit. The heterotrophic organisms isolated were *Bacillins sp*., *Chromobacterium sp*., *Micrococcus sp*, *Enterobacter sp*., and *Psendomonas sp*. The presence of the bacteria in the water bodies (effluent) indicated a regrowth and general bacterial composition of the water. The petroleum degraders isolated in the surface waters where *Chromobacterium sp*., *Micrococcus sp*., *Psendomonas sp*. and *Bacillus sp*. The microorganisms population range from 1.0×10^2 at Elele-Alimini down-stream to 6.0×10^2 at discharge point-Waste pit and the borrow pit at Rumuekpe. The preponderance of petroleum utilizing bacteria in these water samples indicated the presence of hydrocarbons. The fungal count was generally low and was found in Elele-Alimini up-stream and borrow pit near the metering station at Rumuekpe. The mean count of *E. coli* per 100 ml of water was 180+ meaning that all the water samples both surface and groundwater were polluted. The presence of *E. coli* showed faecal pollution of the water and there could be possible presence of pathogenic organisms in the water. This study therefore will be a useful guide to farmers in the areas around the flow stations. There is also need for treatment of surface and groundwater in the area. It is recommended that regular monitoring of the geo-environmental media be carried out.

Keywords: Water; Soil microbiology; Borehole; Pathogen; Metering station

Introduction

The environmental degradation resulting from hydrocarbon exploration and production activities has diverse health and socioeconomic implications on ecosystem functionality and a major concern to all stakeholders globally and the Niger Delta in particular [1]. Major part of soil in the territory of oil and gas fields is characterized by suppression of biological activity. Petroleum hydrocarbons are technogenic wastes, in which the processes of natural self-purification capacity substantially weakened [2]. In uncontaminated soils, microbiological processes intensity varies depending on their physico-chemical properties. In the soils characterized by natural moisture, microbiological processes proceed more intense compared to those, in which geothermal factor is less favorable. Various studies of complete suppression of microbiological degradation of hydrocarbons in highly contaminated areas is explained by hard saturation of soils with heavy oil fractions –asphaltenes and tars that prevent the diffusion of atmospheric oxygen and also by the absence of nitrogen, phosphorus and other biogenic elements that are necessary for microbial activity [3,4]. The anthropogenic influences, stemming from increased industrialization, oil exploration activities, sabotage and illegal refining of petroleum in oil-rich regions, on biogeochemical cycles could impede on soil quality evaluation [5]. Effective determination of contaminated sites can only be achieved with adequate knowledge of the interplay of site specific factors such as geology, nature of the contaminant, pathway receptors linkages, toxicity levels and deployment of appropriate contamination management techniques and legislation. This study therefore is aimed at determining the soil and water microbiological characteristics of Olo Flowstation and Rumuekpe Metering Station in Rivers State, Nigeria and evaluating the concentration and distribution of the physico-chemical, heavy metals in the soils and surface water as well as boreholes around the study area. Moreso, in order to evaluate various strategies employed by microorganisms to adapt to changed environmental conditions under wide perturbations, this study also seeks to evaluate the impact of crude oil pollution on soil microbial community, relevant biochemical indices, possible interactions thereof and to enable efficient evaluation of the possible effect of flow station activities and contamination potential on the physical soil characteristics, assessment of contamination and toxicity levels of hydrocarbon contaminants in the study area as well as suggest sustainable management options.

Geologic Setting of Study Area

The terrain of the study site is of a flat to sub-horizontal

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geomorphologic setting with a measure of undulations due to differential areal erosion. It is located within the Quaternary Sombreiro-Warri plain characterized by dry land with abundant swamp zones, overlying the Tertiary Benin Formation. The soils of the area generally consist of plastic clays to sands and cohesive silts. It has luxuriant freshwater vegetation typical of a tropical rain forest.

The Benin Formation (overlain by quaternary deposits in some places) is the water bearing zone of the area. The sand and sandstones of the Benin Formation are coarse to fine, commonly granular in texture and can be partly unconsolidated. The sands may represent upper deltaic plain deposit and/or braided stream point bars and channel fills. The Shales are few and thin and may represent back swamp deposits [6]. It is overlain by quaternary deposits (40 - 150 m thick) and generally consists of rapidly alternating sequence of sands and silty clays with the latter become increasingly more prominent seawards [7]. The clayey intercalations within the Benin Formation have given rise to multi- aquifer system in the area [6,8-10]. The first aquifer is commonly unconfined while the rest are confined. The average depths for boreholes in the study area are between 50 and 60 meters [11,12].

Deep boreholes in the study area tap water from the confined aquifer from depths up to about 200 m. The study area has been noted to have poor groundwater quality due to objectionable high concentration of certain groundwater parameters and encroachment of saltwater or brackish water into the freshwater aquifers [12,13].

The static water level in the area ranges from 0-1 m during the rainy season and 1-3 m during the dry season. The main source of recharge is through direct precipitation where annual rainfall is as high as 3000 mm [14-16]. The water infiltrates through the highly permeable sands of the Benin Formation to recharge the aquifers. Groundwater in the area occurs principally under water table conditions [13] (Figure 1).

Methods of Study

Soil samples were collected using the grid format and sampling location selected in such a manner as to adequately represent the ecological conditions of the study area. At the grid intersection, soil samples were collected by taking about five auger borings at random around the sampling station to depths of 0-15 cm and compositing the soils from similar depth into well-labelled plastic bags. The quantity of composite samples collected was processed for analyses in the laboratory without sub-sampling in the field. This allowed for more accurate sub-samples that better represented the area and remove errors due to sample splitting and sub-sampling in the field. The analyses were performed on sub-samples of the air-dried soil samples using materials less than 2 mm diameter of the fine earth. Concentrations were expressed on a dry weight basis and the analyses for oil content (THC) were measured using fresh soil samples. Surface and groundwater samples were collected and analyzed using standard methods.

Microbiological assessment involved the analysis of water samples for total aerobic, heterotrophic and petroleum utilizing bacteria, total fungi and petroleum utilizing fungi. These parameters were screened by plating out (by spread plate method) 0.1 ml of diluted sample on each of the appropriate media, using sterile 1 ml pipettes. The abundance of microbial flora was reported as colony forming units (cfu/ml). Heavy metal concentrations (Pb, Cr, Ni and Cd) were determined after extracting with HCl/HNO_3 mixtures. This procedure releases heavy metals tightly bound in clay minerals. The concentrations of the metals were determined by atomic absorption spectrophotometer [17].

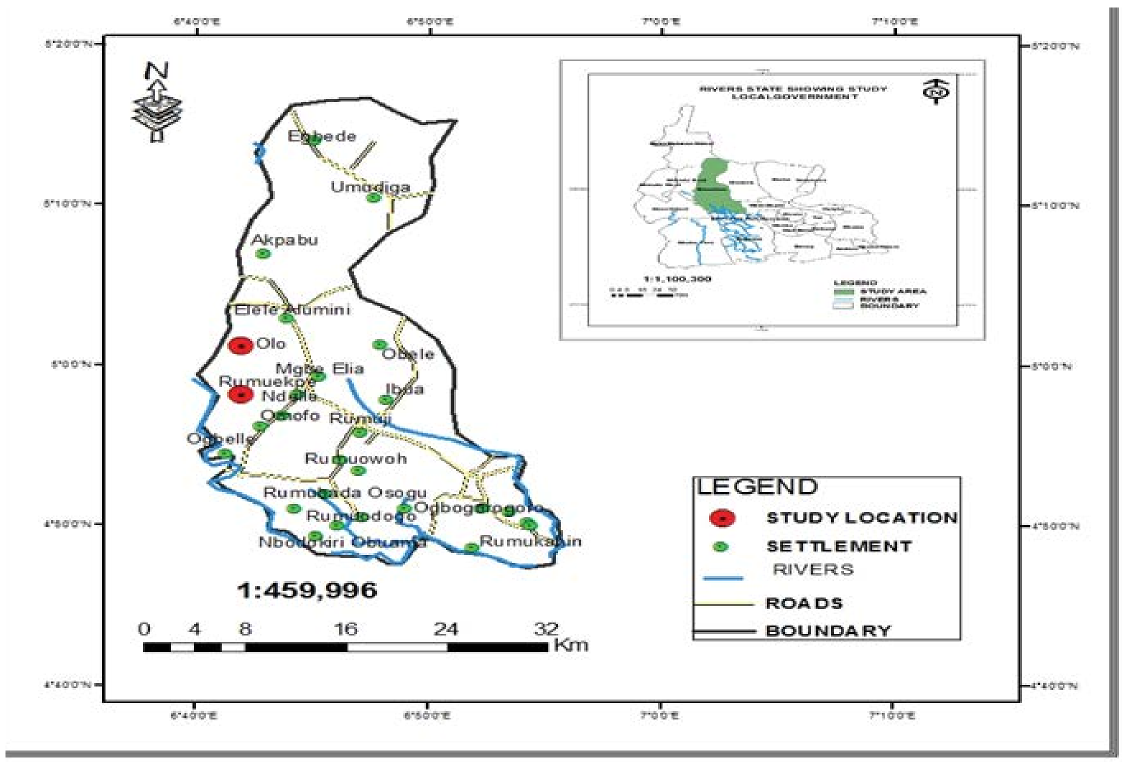

Figure 1: Map showing the study location.

Results and Discussion

Soil microbiology

Results of the microbiological analysis of composite soil samples from each of the various sampling sites in Olo flowstation are presented in Table 1. Results from the transect samples showed that transect OFA has 28.81% and 27.78% of hydrocarbon utilizing bacteria in the surface and subsoil, respectively. Transects OFC, OFE, OFG and OFI had 33.9 and 41.18%, 39.06 and 37.55%, 33.75 and 21.43% and 28.57 and 29.17% of hydrocarbon utilizing bacteria (HUB) respectively for the top and subsoil. These results showed that the percentage of hydrocarbon utilizing bacteria were moderately high in the transect soils. Transect OFC had the highest percentage (HUB) among the transect soils. This might be because this transect was closest to the API, main separators, power generators and the crude oil pipeline all of which have contributed to the high amount of the HUB.

Results of the composite samples from the random samples (OFR) showed that the percent HUB was 40.0% and 27.27% for the top and subsoil, respectively. Though these values were high, they were below expected values in view of the high level of petroleum hydrocarbon spilled on the soils collected. The moderately high amount of hydrocarbon degraders in these soils compared to the control (OFI) indicated that these soils might have been in contact with petroleum products recently which might have polluted the soils.

With the exception of transect OFC which had higher values in the subsoil than the top soil, all other sampling stations had a decrease in percent HUB from the top soil to the subsoil. The poor drainage resulting from stagnant water might have leached the petroleum products down the soil along transect OFC hence resulting into higher HUB% in the subsoil than the top soil. Other sampling stations had better top soil drainage hence lower % HUB down the profile.

Microbiology of surface and groundwater

The result of the microbiological studies of the surface and groundwater is presented in Table 2. All the water samples, both surface and groundwater showed significant range of bacteria. The colonies were within 30 to 300 cfu/ml. The growth for bacteria ranged from 1.5×10^5 cfu/ml at Elele-Alimini (up-stream) to 3.0×10^5 cfu/ml at the waste pit, Sombreiro River and flare pit. The heterotrophic organisms isolated were *Bacillins sp*., *Chromobacterium sp*., *Micrococcus sp*, *Enterobacter sp*., and *Psendomonas sp*. The presence of the bacteria in the water bodies (effluent) indicated a regrowth and general bacterial composition of the water. Table 2 shows the microbiology of surface and subsurface water samples in the area.

The petroleum degraders isolated in the surface waters where *Chromobacterium sp*., *Micrococcus sp*., *Psendomonas sp*. and *Bacillus sp*. The microorganisms population ranged from 1.0×10^2 at Elele-Alimini down-stream to 6.0×10^2 at discharge point- Waste pit and the borrow pit at Rumuekpe. The preponderance of petroleum utilizing bacteria in these water samples indicated the presence of hydrocarbons. The fungal count was generally low and was found in Elele-Alimini up stream and borrow pit near the metering station at Rumuekpe.

There was no growth of fungi at the other water bodies which could be related to the very low oxygen content measured. The mean count of *E. coli* per 100 ml of water was 180+ meaning that all the water samples both surface and groundwater were polluted. The presence of *E. coli* showed recent faecal pollution of the water and there could be possible presence of pathogenic organisms in the water.

Conclusion

This study revealed that the percent Hydrocarbon Utilizing Bacteria (HUB) was 40.0% and 27.27% for the top and subsoil, respectively. The moderately high amount of hydrocarbon degraders in the soils compared to the control indicated that these soils might have been in contact with petroleum products which might have polluted the soils. The poor drainage resulting from stagnant water might have leached the petroleum products down the soil along transect, resulting into higher HUB% in the subsoil than the top soil.

All the water samples, both surface and groundwater showed significant range of bacteria. The colonies were within 30 to 300. The growth for bacteria ranges from 1.5×10^5 cfu/ml at Elele-Alimini (up-stream) to 3.0×10^5 cfu/ml at the waste pit, Sombreiro River and flare pit. The heterotrophic organisms isolated were *Bacillins*

No	Sample code No.	Hydrocarbon Utilizing (cfu/g)	Total Heterotrophic Bacteria (cfu/g)	% Utilizing Bacteria
1	OFA 0 -15 cm	8.5×10^6	2.95×10^7	28.81
2	OFA 15 – 30 cm	5.0×10^6	1.8×10^7	27.78
3	OFC 0 – 15 cm	9.5×10^6	2.8×10^7	33.93
4	OFC 15 – 30 cm	7.0×10^6	1.7×10^7	41.18
5	OFE 0 – 15 cm	1.25×10^7	3.2×10^7	39.06
6	OFE 15 – 30 cm	9.5×10^6	2.75×10^7	34.55
7	OFG 0 – 15 cm	1.35×10^7	4.0×10^7	33.75
8	OFG 15 – 30 cm	7.5×10^6	3.5×10^7	21.43
9	OFI 0 – 15 cm	1.0×10^7	3.5×10^7	28.57
10	OFI 15 – 30 cm	7.0×10^6	2.4×10^7	29.17
11	OFR 0 – 15 cm	1.2×10^7	3.0×10^7	40.0
12	OFR 15 – 30 cm	6.0×10^6	2.2×10^7	27.27
13	RMTI 0-15 cm	1.2×10^7	2.65×10^7	45.28
14	RMT1 15 – 30 cm	7.5×10^6	2.4×10^7	31.25
15	RMT2 0 – 15 cm	1.5×10^7	3.2×10^7	35.94
16	RMT2 15 – 30 cm	6.0×10^6	2.8×10^7	21.43
17	RMT3 0 – 15 cm	1.35×10^7	3.7×10^7	36.49
18	RMT3 15 – 30 cm	8.5×10^6	3.0×10^7	28.33

Table 1: Soil microbiology results of olo flowstation and rumuekpe metering station.

No	Sample	Viable Bacteria Count cfu/ml	Petroleum Utilizing bacteria	Fungal Count cfu/m	Faecal Coliforms Bacteria/100 ml
1	Saver pit	1.6×10^5	ND	-	180
2	Discharge Point	2.5×10^5	6.0×10^2	-	180
3	Flare pit	3.0×10^5	3.0×10^2	-	180
4	Safty (fire) pit	1.6×10^5	ND	-	180
5	Waste pit	3.0×10^5	6.0×10^2	-	180
6	Alimini up	1.5×10^5	3.0×10^2	3.0×10^2	180
7	Alimini down	2.0×10^5	1.0×10^2	-	180
8	Sombreiro River	3.0×10^5	4.0×10^2	-	180
9	Burrow pit	2.0×10^5	6.0×10^2	1.0×10^2	180
	DPR Limit				
10	Borehole 1	2.5×10^4	-	-	180
11	Borehole 2	3.1×10^4	-	-	180
12	Borehole 3	2.0×10^4	-	-	180

Table 2: Microbiology surface and subsurface water samples.

sp., *Chromobacterium sp*., *Micrococcus sp*, *Enterobacter sp*., and *Psendomonas sp*. The presence of the bacteria in the water bodies (effluent) indicated a regrowth and general bacterial composition of the water. The petroleum degraders isolated in the surface waters where *Chromobacterium sp*., *Micrococcus sp*., *Psendomonas sp*. and *Bacillus sp*. The microorganisms population range from 1.0×10^2 at Elele-Alimini down-stream to 6.0×10^2 at discharge point-Waste pit and the borrow pit at Rumuekpe. The preponderance of petroleum utilizing bacteria in these water samples indicated the presence of hydrocarbons. The fungal count was generally low and was found in Elele-Alimini up-stream and borrow pit near the metering station at Rumuekpe. The mean count of *E. coli* per 100 ml of water was 180+ meaning that all the water samples both surface and groundwater were polluted. The presence of *E. coli* showed faecal pollution of the water and there could be possible presence of pathogenic organisms in the water. This study will guide farming activities in the areas around the flow stations as well as treatment of surface and groundwater which serve as the sources of water for drinking and domestic activities in the area.

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