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EFFECT OF CRUDE OIL SPILLAGE ON SOME SOIL PHYSICAL PROPERTIES WITHIN OVIA NORTH EAST LOCAL GOVERNMENT IN EDO STATE.

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ABSTRACT

The release of crude oil into the environment by oil spill is currently receiving a worldwide attention due to the high risk it portends to the health of the environment. The purpose of this study was to determine the effect of crude oil spillage on some soil physical properties. Eight (8) soil samples were collected from eight sampling locations around the flow station at Gelegele River, Edo State. The total petroleum hydrocarbon (TPH) recorded were above the 1,000 mg/kg permissible limit by World Health Organization (WHO) and United States Environmental Protection Agency (USEPA) for hydrocarbon contaminated soil. The physiochemical studies were carried out according to the methods of Association of Official Analytical Chemist (A.O.A.C) for the determination of the soil physicochemical parameters. The physiochemical parameters obtained were pH (6.01 ± 0.02 – 6.49 ± 0.07), Electrical Conductivity (EC) (416.00 ± 10.70 – 656.45 ± 11.65) mS/m, Carbon (2.13 ± 0.03 – 3.70 ± 0.01^{a}) %, Nitrogen (0.04 ± 0.01 – 1.67 ± 0.02^{ab}) %, Phosphorus (1.33 ± 0.06 – 2.91 ± 0.04^{ab})%, Water holding capacity (WHC) (82.48 ± 0.82 – 92.48 ± 0.82) %, Bulk density (0.70 ± 0.02^{ab} – 2.79 ± 0.05) %. There is a current concern of environmental pollution and this study showed that the area of study currently of concern that needs to be monitored.

INTRODUCTION

There is growing public concern as a wide variety of toxic chemicals are being introduced inadvertently or deliberately into the environment. Petroleum hydrocarbons are one common example of these chemicals, which enter the environment frequently and in large volumes through numerous routes. Petroleum hydrocarbons come into the environment through accidents, spills or leak, urban input, industrial releases and commercial or domestic uses (Ou *et al*., 2004). Soil contaminated with petroleum hydrocarbons is a seriously urgent worldwide environmental problem. Soil polluted with organic compounds such as hydrocarbon products pose an environmental problem challenge world-wide (Erika *et al*., 2011). The term hydrocarbon has been used to describe petroleum complex mixtures in which there are hundreds of organic compounds ranging from light, volatile, short-chained, long-chained and branched compounds (Wong *et al*., 1997). Studied properties of soils include soil texture, moisture content, density, soil organic matter, pH, electrical conductivity and cation exchange capacity, among others.

Oil pollution has deleterious effect on plant growth, soil macronutrients, microorganism and the terrestrial ecosystem in general (Osuji, 2002). Petroleum and its derivatives released in the environment either accidentally or deliberately pose problems of increasing magnitude throughout the world (Okoh and Trejo-Hernandez, 2006). One of the most important characteristics of hydrocarbon degrading bacteria is the ability to emulsify hydrocarbons in solution by producing surface active agents such as bio-surfactants (Bredholt *et al.*, 1998). Environmental contamination with petroleum hydrocarbons has increased all over the world with the growing societal and industrial demands for them. Adverse effects of petroleum hydrocarbon contaminants on biological, chemical, and physical reactions of soil may be critical for maintaining physicochemical and biological properties which are responsible for soil quality. Petroleum-contaminated soil can be decontaminated by environmental-friendly and cost-effective natural remediation techniques (Alkorta and Garbisu, 2001) such as bio-stimulation and bio-augmentation through enhancing the activity of hydrocarbon degrading microbes in contaminated soil (Towell *et al.*, 2011). The characterization of contaminated soil is a crucial step in the planning remediation program for oil-contaminated soil (Mao *et al.*, 2009). As such, analyses of both soil physicochemical and biological parameters are vitally important in the characterization of petroleum-contaminated soil. Results of chemical analyses are widely used as indicators of hydrocarbon toxicity in the characterization of petroleum contaminated soil (Mao *et al.*, 2009). However, a reduced contaminant concentration may not always indicate a decrease in soil toxicity (Al-Mutairi *et al.*, 2008) due to the possibility of producing toxic metabolites in soil during bioremediation thus the microbiological characterization and identification is needed (Loibner *et al.*, 2003). The objective of this study was to investigate the effect of hydrocarbon contamination on some soil physical parameters.

MATERIALS AND METHODS

Study site

The site used in this study was around the flow station at Gelegele Seaport in Ovia North East Local Government, Edo State. Benin City is the capital and largest city of Edo State in Southern Nigeria. It is the fourth largest city in Nigeria after Lagos, Kano and Ibadan, with a population of 1,782,000 as of 2021. It is situated approximately 40 kilometers (25 ml) north of the Benin river and 320 kilometers (200 ml) by road east of Lagos. Gelegele is a village located in Ovia North East Local Government Area of Edo State, Nigeria

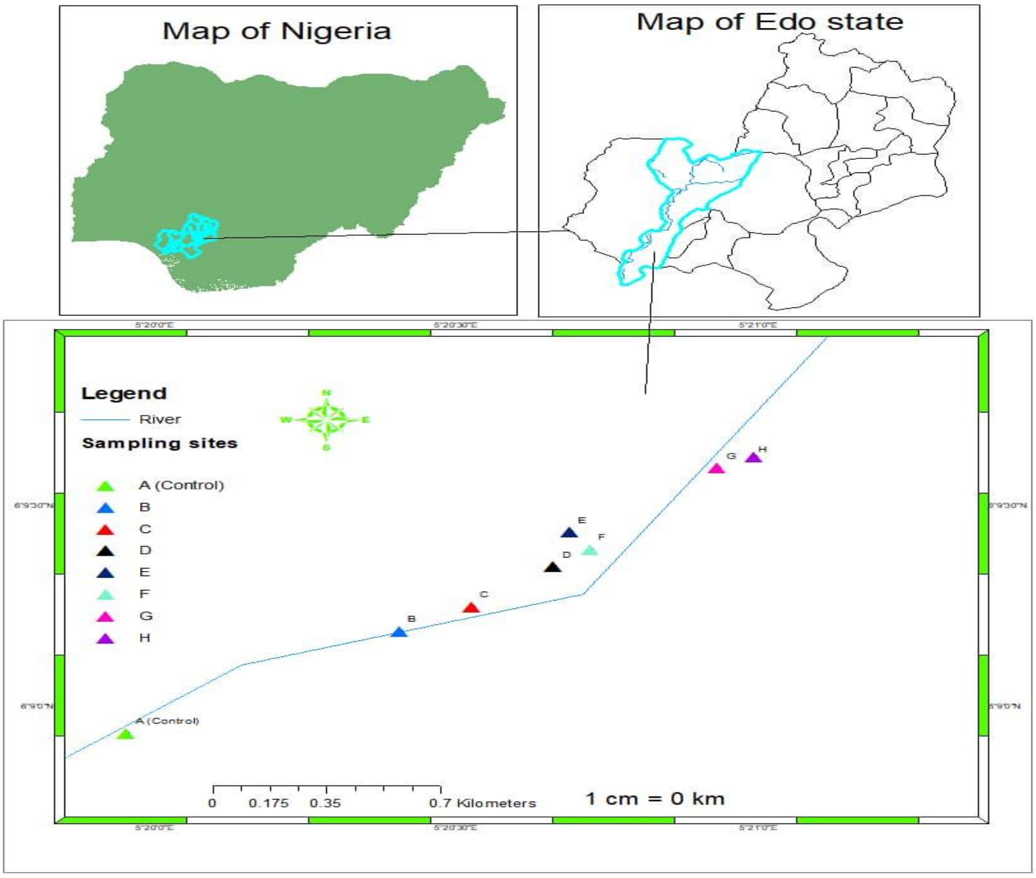

Figure 1: Map showing GPS coordinates of soil samples collected around the flow station of Gelegele River. (Key: A, B, C, D, E, F, G and H are the sampling sites)

Sample collection

Soil samples of approximately 1kg (0 – 120 cm depth) were collected from around the flow station at different locations along the shore line of Gelegele River, Edo State, (Figure 1). Samples were collected to represent a range of hydrocarbon contaminated soil and to represent various sources of pollution. Samples were collected in plastic bags and transported to the laboratory for analysis.

Determination of total petroleum hydrocarbon (TPH)

Five grams (5 g) of crude oil contaminated soil was suspended in 25 ml of hexane and shaken for 20 min using a shaker. The mixture was filtered using a Whatman No 1 filter paper and the filtrate diluted by transferring 1 ml of the extract into 50 ml of hexane. The absorbance of this mixture was read at 460 nm with HACH DR/2010 Spectrophotometer using n-hexane as blank (Adesodun and Mbagwu, 2008).

The actual TPH concentration in mg/kg was deduced as follows

The actual TPH concentration (mg/kg) was deduced as follows;

$$\text{TPH} = \frac{\text{Instrument reading (Conc. obtained from calibration) x Volume of extract (ml) x DF}}{\text{Weight of sample (kg)}}$$

Where TPH = Total petroleum hydrocarbon, DF = Dilution factor, Conc. = Concentration

Physiochemical properties of the soil samples

The physiochemical properties of the soil samples were investigated according to the methods of A.O.A.C (2000).

RESULTS

The search carried out to determine the effect of crude oil spillage on some soil physical properties within Ovia North East Local Government in Edo State revealed the following results.

Figure 1 was the result of the total petroleum hydrocarbon (TPH) which showed that the range of TPH contamination was between 216.16 ± 71.21 mg/kg – 4928.80 ± 61.35^{ab} mg/kg.

Table 1 revealed the physicochemical properties of crude oil contaminated soil samples. The result showed that across all the sampling sites (A to H), pH ranged from (6.01 ± 0.02 – 6.49 ± 0.07), Electrical Conductivity (EC) (416.00 ± 10.70 – 656.45 ± 11.65) mS/m, Carbon (2.13 ± 0.03 – 3.70 ± 0.01^{a}) %, Nitrogen (0.04 ± 0.01 – 1.67 ± 0.02^{ab}) %, Phosphorus (1.33 ± 0.06 – 2.91 ± 0.04^{ab})%, Water holding capacity (WHC) (82.48 ± 0.82 – 92.48 ± 0.82) %, Bulk density (0.70 ± 0.02^{ab} – 2.79 ± 0.05) %.

Table 2 revealed the soil texture result across sampling site A (control) to sampling site H, where silt ranged from 18.10 ± 14.90 % - 65.75 ± 0.43^{ab} %, clay ranging from 16.55 ± 1.35^{a} % - 36.45 ± 2.75^{a} % and sand ranging from 11.15 ± 4.45^{a} % - 52.30 ± 8.60^{a} %. Sampling site H had the highest silt content of 65.75 ± 0.43^{ab} which showed significance to normal control. Sampling site D had the highest clay content of (36.45 ± 2.75) % which is not significant to normal control. Sampling site B had the highest sand content (52.30 ± 8.60^{a}) % which was significant to normal control.

Table 3 revealed that the cation exchange capacity (CEC) showed that Na ranged from (0.35 ± 0.04^{a} – 0.84 ± 0.01^{ab}) cmol$_c$/kg, K (0.34 ± 0.02^{ab} – 2.11 ± 0.03^{ab}) cmol$_c$/kg, Mg (1.56 ± 0.08^{a} – 4.31 ± 0.13^{ab}) cmol$_c$/kg, Ca (3.70 ± 0.33^{a} – $24.01 \pm 0.03^{ab.}$) cmol$_c$/kg.

Table 4 revealed the result of the heavy metal analysis where Lead had (0.11 ± 0.02^{ab} – 0.65 ± 0.03^{a}) mg/kg, Copper (0.85 ± 0.02 – 1.73 ± 0.05^{ab}) mg/kg, Cadmium (0.09 ± 0.01 – 0.26 ± 0.02^{ab}) mg/kg, Chromium (0.35 ± 0.04 – 0.95 ± 0.04^{ab}) mg/kg, and Iron (2.46 ± 0.04 – 10.95 ± 1.92^{ab}) mg/kg.

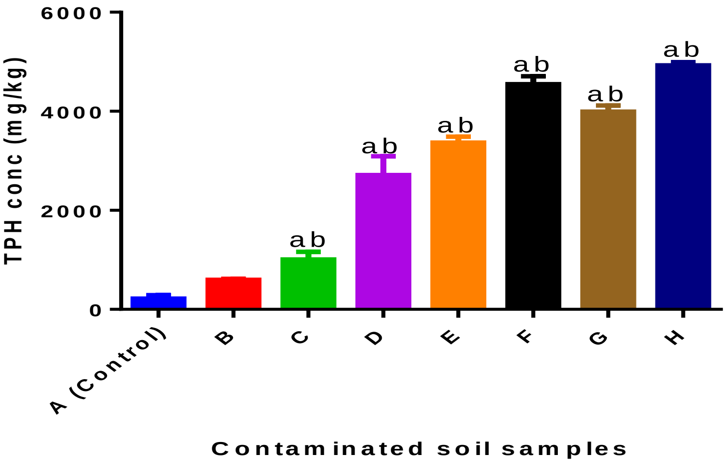

Figure 1: Total petroleum hydrocarbon (TPH) of contaminated soil sample. $^{ab}P < 0.0001$ compare to normal control. The samples were represented as Mean ± SEM, where n=3

Key: A = Sampling site A (control sample) (N 06.14888 E 005.33254), B (sampling site B) (N 06.15311 E 005.34011), C (sampling site C) (N 06.15414 E 005.34210), D (sampling site D) (N 06.15581 E 005.34436), E (sampling site E) (N 06.115725 E 005.34481), F (sampling site F) (N 06.15653 E 005.34535), G (sampling site G) (N 06.15991 E 005.334887), H (sampling site H) (N 06.16039 E 005.34989)

Table 1: Physiochemical properties of hydrocarbon contaminated soil samples

Parameters	Sample A	Sample B	Sample C	Sample D	Sample E	Sample F	Sample G	Sample H
pH	6.19 ± 0.14	6.01 ± 0.02	7.01 ± 0.09^{a}	6.48 ± 0.09	6.26 ± 0.11	6.49 ± 0.07	6.47 ± 0.32	6.40 ± 0.03
EC (mS/m)	794.45 ± 31.65	719.30 ± 191.40	456.0 ± 10.70	493.90 ± 14.70	417.50 ± 19.60	567.15 ± 37.75	616.05 ± 10.85	592.30 ± 27.10
Carbon (%)	3.34 ± 0.04	2.13 ± 0.03^{ab}	2.44 ± 0.15^{ab}	3.10 ± 0.02	3.65 ± 0.13	3.66 ± 0.03	3.90 ± 0.04^{a}	3.70 ± 0.01^{a}
Nitrogen (%)	0.04 ± 0.01	1.44 ± 0.12^{ab}	0.84 ± 0.07^{a}	0.53 ± 0.04^{a}	0.98 ± 0.07^{ab}	0.81 ± 0.18^{a}	1.02 ± 0.11^{ab}	1.67 ± 0.22^{ab}
Phosphorus (%)	1.73 ± 0.02	1.33 ± 0.06	1.38 ± 0.19	1.55 ± 0.02	1.66 ± 0.03	1.76 ± 0.03	2.50 ± 0.07^{ab}	2.91 ± 0.04^{ab}
WHC (%)	90.80 ± 0.80	88.30 ± 5.00	82.48 ± 0.82	86.65 ± 1.65	86.65 ± 3.35	89.15 ± 0.85	89.15 ± 0.85	92.48 ± 0.82
Bulk density (g/cm^3)	2.67 ± 0.02	0.70 ± 0.02^{ab}	0.90 ± 0.03^{ab}	2.79 ± 0.05	2.46 ± 0.16	2.82 ± 0.02	2.85 ± 0.08	2.71 ± 0.01

The values were the means±SEM for the physiochemical properties analyzed of the soil samples. Significance at $p < 0.05$ with respect to normal control.

Key: A = Sampling site A (control sample) (N 06.14888 E 005.33254), B (sampling site B) (N 06.15311 E 005.34011), C (sampling site C) (N 06.15414 E 005.34210), D (sampling site D) (N 06.15581 E 005.34436), E (sampling site E) (N 06.115725 E 005.34481), F (sampling site F) (N

06.15653 E 005.34535), G (sampling site G) (N 06.15991 E 005.334887), H (sampling site H) (N 06.16039 E 005.34989), a= Significant, ab= Highly significant

Table 2: Soil texture of hydrocarbon contaminated soil samples

Parameters (%)	Sample A	Sample B	Sample C	Sample D	Sample E	Sample F	Sample G	Sample H
Silt	24.10 ± 14.90	27.65 ± 1.55	33.90 ± 3.20	45.73 ± 1.83^{a}	55.15 ±2.25^{ab}	63.95 ±2.79^{ab}	62.84 ±1.53^{ab}	65.75 ±0.43^{ab}
Clay	37.00 ± 3.50	18.75 ± 1.35^{a}	18.25 ± 1.15^{a}	36.45 ± 2.75	33.70 ± 2.20	24.37 ± 2.51	25.90 ±1.53	21.82 ± 0.89^{a}
Sand	38.90 ± 1.30	53.60 ± 8.60^{a}	47.85 ± 4.35^{a}	17.82 ± 4.58^{a}	11.15 ± 4.45^{a}	11.68 ± 0.13^{a}	11.26 ± 0.01^{a}	12.43 ± 0.47^{a}

The values were the means±SEM for the soil texture analyzed of the soil samples. Significance at $p < 0.05$ with respect to normal control.

Key: A = Sampling site A (control sample) (N 06.14888 E 005.33254), B (sampling site B) (N 06.15311 E 005.34011), C (sampling site C) (N 06.15414 E 005.34210), D (sampling site D) (N 06.15581 E 005.34436), E (sampling site E) (N 06.115725 E 005.34481), F (sampling site F) (N 06.15653 E 005.34535), G (sampling site G) (N 06.15991 E 005.334887), H (sampling site H) (N 06.16039 E 005.34989)

a= Significant

ab= Highly significant

Table 3: Results of cation exchange capacity of hydrocarbon contaminated soil samples

Parameters (cmol$_c$/kg)	Sample A	Sample B	Sample C	Sample D	Sample E	Sample F	Sample G	Sample H
Na	0.57 ± 0.01	0.35 ± 0.04^{a}	0.46 ± 0.02	0.65 ± 0.03	0.56 ± 0.04	0.73 ± 0.02^{a}	0.84 ± 0.01^{ab}	0.58 ± 0.03
K	1.10 ± 0.02	0.41 ± 0.02^{ab}	0.34 ± 0.02^{ab}	1.27 ± 0.02^{a}	1.64 ±0.03^{ab}	1.81 ± 0.02^{ab}	2.11 ± 0.03^{ab}	1.60 ± 0.04^{ab}
Mg	2.13 ± 0.06	1.56 ± 0.08^{a}	1.87 ± 0.03	2.16 ± 0.04	2.50 ± 0.07^{a}	2.70 ± 0.06^{a}	4.31 ± 0.13^{ab}	3.13 ± 0.05^{ab}
Ca	5.98 ± 0.05	3.70 ± 0.33^{a}	11.46 ±0.43^{ab}	14.48 ± 0.39^{ab}	18.26 ± 0.14^{ab}	21.60 ± 0.77^{ab}	24.01 ± 0.03^{ab}	19.52 ± 0.22^{ab}

The values were the means±SEM for the cation exchange capacity analyzed of the soil samples. Significance at $p < 0.05$ with respect to normal control.

Key: A = Sampling site A (control sample) (N 06.14888 E 005.33254), B (sampling site B) (N 06.15311 E 005.34011), C (sampling site C) (N 06.15414 E 005.34210), D (sampling site D) (N 06.15581 E 005.34436), E (sampling site E) (N 06.115725 E 005.34481), F (sampling site F) (N 06.15653 E 005.34535), G (sampling site G) (N 06.15991 E 005.334887), H (sampling site H) (N 06.16039 E 005.34989)

a= Significant
ab= Highly significant

Table 4: Results of heavy metal analysis of hydrocarbon contaminated soil samples

Parameters (mg/kg)	Sample A	Sample B	Sample C	Sample D	Sample E	Sample F	Sample G	Sample H
Lead	0.45 ± 0.02	0.11 ± 0.02^{ab}	0.18 ± 0.01^{ab}	0.35 ± 0.02	0.50 ± 0.02	0.33 ± 0.02^{a}	0.65 ± 0.03^{a}	0.59 ± 0.03^{a}
Copper	0.85 ± 0.02	1.15 ± 0.02^{a}	0.93 ± 0.02^{a}	1.11 ± 0.01	1.48 ± 0.09^{ab}	1.35 ± 0.03^{ab}	1.73 ± 0.05^{ab}	1.69 ± 0.08^{ab}
Cadmium	0.09 ± 0.01	0.15 ± 0.03	0.15 ± 0.02	0.18 ± 0.01^{a}	0.22 ± 0.02^{a}	0.26 ± 0.02^{ab}	0.30 ± 0.01^{ab}	0.26 ± 0.01^{ab}
Chromium	0.35 ± 0.04	0.46 ± 0.03	0.54 ± 0.03^{a}	0.64 ± 0.03^{a}	0.85 ± 0.04^{ab}	0.92 ± 0.03^{ab}	1.05 ± 0.02^{ab}	0.95 ± 0.04^{ab}
Iron	2.46 ± 0.04	4.78 ± 0.05	2.70 ± 0.09	5.55 ± 0.23	7.23 ± 0.07^{a}	5.71 ± 0.37	10.95 ± 1.92^{ab}	8.10 ± 0.07^{a}

The values were the means±SEM for the heavy metals analyzed for the soil samples. Significance at $p < 0.05$ with respect to normal control.

Key: A = Sampling site A (control sample) (N 06.14888 E 005.33254), B (sampling site B) (N 06.15311 E 005.34011), C (sampling site C) (N 06.15414 E 005.34210), D (sampling site D) (N 06.15581 E 005.34436), E (sampling site E) (N 06.115725 E 005.34481), F (sampling site F) (N 06.15653 E 005.34535), G (sampling site G) (N 06.15991 E 005.334887), H (sampling site H) (N 06.16039 E 005.34989)

a= Significant

ab= Highly significant

DISCUSSION

Figure 1 revealed that the results of the total petroleum hydrocarbon (TPH) value of sampling site A which was control had the lowest value 216.16 ± 71.21 mg/kg indicating less contamination, while sampling site H had the highest value 4928.80 ± 61.35^{ab}, indicating a higher hydrocarbon contamination. This result is statistically significant in comparison with normal control. The result of TPH in this study above is more than the acceptable regulatory standard value of 1,000 mg/kg concentration of TPH in polluted soil (DPR, 2002). In this research the highest TPH value gotten was 4928.80 ± 61.35^{ab} which was higher than the guideline given by DPR (2002). This implies that the environment is already experiencing hydrocarbon toxicity. The report of Alinnor *et al*. (2014) of TPH values of 1,242 mg/kg – 5,200 mg/kg of hydrocarbon contaminated soils in communities in Niger Delta region was high than TPH value reported in this study. The research of Alinnor and Nwachukwu (2013) reported value of TPH of 3,307 mg/kg in a research where polluted soil samples were collected from different locations in some communities in River State. This value falls within the range reported in this study. Sari *et al.* (2017) reported TPH values ranging from 559.87 mg/kg – 107,189.63 mg/kg from hydrocarbon contaminated soil samples. This is far above what was revealed in this study, this shows that the TPH values can be very high due to hydrocarbon pollution. TPH consist of aliphatic and aromatic hydrocarbons that consist of $C_{5\text{-}35}$ chains with various structural carbon atoms configuration, how complex the atomic structure is, will determine how hydrophobic the hydrocarbon compound will manifest (William *et al.*, 2005). Most petroleum hydrocarbon compounds are carcinogenic and constant exposure to them by humans can lead to various health challenges (Osuji *et al*., 2005).

Table 1 revealed the physicochemical properties of the crude oil contaminated soil samples. The results showed that across all the sampling sites (A to H) there were significances in the results with respect to normal control. Studies have shown that the physiochemical properties of soil can be affected by hydrocarbon contamination. These physiochemical properties are suspected to aid the proliferation of the bacteria in the soil. The interaction between living organisms and the petroleum contaminants is highly dependent on the kind of soil (Hreniuc *et al*., 2015). Studies have shown that the pH of a soil influences the uptake of nutrients by plants and also affect directly the interaction of microbes, their proliferation and their potential in carrying out bioremediation. In this study the pH was within a comfortable range which could aid the bacteria isolated from the soil to be able to carry-out its bioremediation activities. Soil pH is a key factor that influences the uptake of available nutrients in the soil for plant utilization (Marschner, 1995). The research carried out by Bada *et al*. (2018) was with-in the pH range gotten in this study which has been reported to aid and favour microbial metabolic activities. The study of Okoh (2006) reported that low or acidic pH affected the rate of oil biodegradation by bacteria in oil contaminated soil. Acidic soil causes a lot of problem for agricultural because a lot of metallic cations such as Cd, Ni, Pb, Cu, Hg and Zn are released into the soil (Bada *et al*., 2014). The significantly higher values of electrical conductivity values obtained from the various sampling site in this study could have resulted from high concentration of charged ions in the impacted sites. The research of Oyem and Oyem (2013) revealed electrical conductivity values between the range of (19.6 – 145.0) µs/cm, the lower values could be as a result of the occurrence of nitrate salt leaching taking place in the Niger Delta. The results of the electrical conductivity in this study was between 417.50 ± 19.60 – 794.45 ± 31.65, this high value could be as a result of the presence of high Na^+ and Mg^+ salts in the environment. This was in agreement with the research carried out by Abosede (2013), Sari *et al*., (2018), Oyem and Oyem (2013). The research of Abdulfattah *et al*. (2016), Precti and Shah (2015) reported from the research on hydrocarbon contaminated soil that electrical conduct can be affected by oil pollution.

Table 2 is the result of the soil texture of the hydrocarbon contaminated soil. The result showed that across the sampling site A (control) to sampling site H, the percentage of sand, clay and silt varied in values. In this research, sampling site H had the highest silt content of 65.75 ± 0.43^{ab} which showed significance to normal control. Higher silt content in soil results in slower hydrocarbon degradation and poor water intake. Sampling site H in this research had the highest water holding capacity of 92.48 ± 0.82 %. Sampling site D had the highest clay content of 36.45 ± 2.75 which was not significant to normal control. Sampling site B had the highest sand content of 52.30 ± 8.60^a, thereby having the highest rapid water/hydrocarbon infiltration and poor water holding capacity and low nutrient storage ability. The results in this study is in agreement with a research carried out by Oyem and Oyem (2013) where the result for hydrocarbon polluted soil collected from Orgonoko quarters in Delta State had average of 57.00 % sand, 32.75 % clay and 10.25 % silt. In Kana quarters the average soil texture was 73.75 % sand, 20.00 % clay and 6.25 % silt. In Arunton areas for sampling point 1, the sand content was 53.5 %, clay 42.5

% and silt 4.0 %. Sampling point 2 had 53.75 % sand, 42.5 % clay and 3.75 % silt. The presence of hydrocarbon pollution affected the proportion of sand, silt and clay content in this study just like others studies reported. A soil with a low percentage of silt and clay but with a high sand content will affect the presence and release of essential nutrients from the soil to plants. The result of the soil texture of this study is similar to the research of Oyem and Oyem (2013), Udo and Chukwu (2014) of soil hydrocarbon contaminated sites.

Table 3 is the result of cation exchange capacity (CEC) which is affected by soil pH, soil organic matter content and soil type. The CEC organic matter of soil and minerals in clay varies with pH. The cation exchange capacity (CEC) is lowest at a pH of soil of 3.5 - 4.0 and increases with increasing pH. The CEC of soil is an indication of the soil capacity to retain and exchange cation elements. Therefore, high CEC content provides the opportunity for higher negative charge and better ability for the soil to hold cations. An increase in CEC values will make more nutrients to be available in the soil particles which will favour better absorption of essential nutrients by plants. Soils are able to hold water better when their CEC value is high (like clay soil), while a lower CEC value of soil leads to poor water holding ability (like sandy soils). The soils with low cation exchange capacity group have values below 10 cmol_c/kg, while soils with the high cation exchange capacity group have values greater than 20 cmol_c/kg. The results in Table 3 revealed that apart from Ca, all others such as Na, K, Mg have all their CEC values below 10 cmol_c/kg, this implies that the hydrocarbon pollutant greatly influenced the soil and therefore had negative impact on the soil ability to retain necessary and essential nutrients needed for plant growth. The research of Dai *et al*. (2018) showed that CEC results ranged from 6.63 cmol_c/kg – 41.65 cmol_c/kg of agricultural soils, which falls within the range of higher CEC group with values above 10 cmol_c/kg. This result is in variance with the results of this research because the soil was free from hydrocarbon pollution, while the soil in this study was negatively impacted by hydrocarbon pollution.

The results in Table 4 revealed that across all the sampling sites, the results of the heavy metals analyzed were below the permissible limit given by WHO (1996). The result of heavy metals in this study supports the research of Ogundele *et al.* (2015). High heavy metal content in the body has been reported by several researches to cause harm to human health (Alloway and Ayres 1998). The level of hydrocarbon contamination of soil influences the absence or presence of these heavy metals, which also influences the nutrient status of the soil.

CONCLUSION

This study was able to reveal that the soil samples collected from the flow station were high in total petroleum hydrocarbon beyond the acceptable limit by regulatory organizations connoting hydrocarbon pollution of the environment. Results from the polluted sites of the Gelegele river and the unpolluted sites revealed high levels of hydrocarbon contamination of the polluted sites. This implies low soil fertility, negative impact in the economic life of the indigenes, reduce source of livelihood in the affected areas. There was slight significant difference in electrical conductivity, cation exchange capacity, soil texture and this helps to determine the soil fertility. Physical properties of soil can be affected by hydrocarbon soil pollution.

Conflict of Interest

There is no conflict of interest associated with this work.

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