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ASSESSMENT OF THE PHYSICOCHEMICAL PROPERTIES OF PETROLEUM CONTAMINATED SOILS IN BARANYONWA DERE, GOKANA, RIVERS STATE, NIGERIA

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ABSTRACT

This study was employed to assess the physicochemical properties in crude oil - contaminated soil in Baranyonwa Dere (B. Dere) in Gokana Local Government Area of Rivers State, Nigeria. Oil polluted soil samples were collected from different sampling sites at depths of 0-15cm and 15-30cm and analyzed using standard analytical techniques. The temperature of the uncontaminated soils (29.50 ± 0.29) showed a significant increase when compared to that of the oil polluted soils (27.50 ± 0.29) at p>0.05. pH of the contaminated oil soils (5.25 ± 0.03) showed a significant decrease when compared to that of the uncontaminated soils (6.15 ± 0.15). The electrical conductivity of the contaminated soils recorded a significant increase (303.95 ± 1.14) when compared to that of the uncontaminated soils (127.56 ± 1.53). Moisture content of the contaminated soils (11.21 ± 0.03) showed no significant difference compared to that of the uncontaminated soils (8.68 ±0.35). The chloride concentration of the contaminated soils (39.01 ± 0.63) was significantly higher than that of the uncontaminated soils (17.14 ± 0.29). Nitrate (6.05 ± 0.03) and nitrite (2.03 ± 0.03) concentrations of the contaminated soils showed a significant increase when compared to that of the uncontaminated soils (1.10 ± 0.01 and 0.16 ±0.01) respectively. Phosphate (7.14 ± 0.01) and sulphate (84.06 ±0.00) concentrations of the contaminated soils were significantly higher than that of uncontaminated soils at p<0.05. The TOC of the contaminated soils (18.81 ± 0.05) was slightly higher than that of the uncontaminated soil (8.81 ± 0.35) at p< 0.05. The percentage of organic matter of the contaminated soils (70.98 ±0.001) was significantly higher than that of the uncontaminated soil (15.24 ± 0.15). The TPH of the contaminated soil (27.90 ± 0.45) was slightly higher when compared to that of the uncontaminated soils (12.84 ±0.02) (p<0.05). While the percentage concentration of the silt, clay and sand showed no significant difference when compared to that of the uncontaminated soils samples (p<0.05). The results revealed the abundance of microorganisms in the oil polluted soils. Soil bacterial community can be enhanced by organic matter which can produce needed support for the bacterial community to work efficiently.

KEYWORD: *Crude Oil, Oil Spillage, Oil Polluted Soil, Physico-chemistry, Bacteria*

INTRODUCTION

Nigeria has been recognized as the country that possesses the largest oil and gas reserve in Africa (Adati, 2012). Oil spill, which is the release of petroleum hydrocarbons into the environment, has been a recurring occurrence in the Niger Delta region for several decades. This has resulted to environmental pollution bringing about a significant and detrimental impacts on extensive areas of both terrestrial and aquatic inhabitants (Elum *et al.,* 2016). Crude oil pollution is a perennial environmental problem affecting the ecosystem in Niger Delta region in Nigeria (Ndekhedehe *et al.,* 2023). Approximately, 2 million tonnes of oil are discharged into the environment each year as a result of both human activities and natural occurrences. The impact of an oil spill is contingent upon the specific type of oil that was released and the location of the spill, whether it occurred on land, in a river, or in the ocean (Ezekoye *et al.,* 2018). The majority of the impact is attributed to the physical properties of the oil (Gayathiri *et al.,* 2017).

The physiochemical status of the soils within the Niger region have been altered drastically due to these oil spills and long term of neglect of the oily waste discharge into the environment (Osuagwu and Olaifa, 2018). The physiochemical integrity of the soil in this region is therefore questionable. It is important therefore to determine the physicochemical status of the contaminated soil samples in polluted environment (Chikere *et al.,* 2018). There will be absorption and accumulation of hazardous substances as petroleum products, within the food chains. However, it concurrently exerts adverse effects on less productive soils by inducing contamination, which in turn can have adverse effects such as significantly reducing nutrients content and increasing presence of hydrocarbon compounds (Ahmad and Egbodion, 2013). Petroleum contamination affects the physical and chemical properties such as temperature, pH, electrical conductivity, moisture content, chloride, nitrate, nitrite, phosphate, sulphate, total organic carbon, total petroleum hydrocarbon and particle size.

The process of bio-stimulation helps overcome the challenge of nutrient limitation. The most commonly added nutrients (Nitrogen and Phosphate) are often limiting in the soil environment. Bio-stimulation has the potential to expedite naturally occurring processes (Ogbonna, 2018). This approach relies on the stimulation of catabolic activities in native microorganisms through the introduction of organic and inorganic and inorganic materials that are rich in nutrients (Abioye *et al.,* 2010). Additionally, the strategy involves the provision of oxygen or other electron acceptors such as sulphate, nitrate and nitrite, as well as maintenance of optimal conditions in terms of temperature, pH and moisture (Kumari *et al.,* 2013).

In the process of bioremediation, microorganisms employ chemical contaminants present in the soil as a source of energy. Through oxidation-reduction reactions, these microorganisms metabolize the specific target contaminant, converting it into the form of energy that can be utilize by the microorganisms. The metabolites that are discharged into the environment as by-products exhibit reduced toxicity compared to the original contaminants. In the presence of oxygen hydrocarbon undergoes oxidation which necessitates a simultaneous reduction of an electron acceptor which means oxygen experiences reduction, while in the absence of oxygen, the outcome is the production of carbon dioxide and water (Clayton *et al.,* 2016). The aim of this study was to determine the physicochemical properties of oil polluted soil samples in B-dere, Gokana Local Government Area of Rivers State, Nigeria thereby assessing the physical structure and health of the soil in the contaminated site.

Study Area

Baranyonwa Dere (B. Dere) is located in Gokana Local Government Area of Rivers State, Nigeria. Its approximate GPS coordinates are 4.66934°N, 7.27407°E, with an elevation of about 19 meters (62 feet) above sea level (Mapcarta, 2025). B. Dere, like the rest of Gokana, has a tropical climate, characterized by high humidity and temperatures averaging 26–27°C. The area experiences significant rainfall, typical of the Niger Delta region (Townsvillages, 2025). The region falls within the Niger Delta tropical rainforest zone, featuring swamp forests, mangroves, and lowland rainforests, which contribute to the area's rich biodiversity and ecological significance (Buzznigeria, 2025). B. Dere and the broader Gokana area have a lowland terrain, with elevations ranging between 15 to 24 meters above sea level. This relatively low altitude makes the area prone to flooding, particularly during heavy rainfall (Mapcarta, 2025).

The land use in B. Dere is predominantly agricultural, with significant portions dedicated to subsistence farming, oil palm plantations, and fishing activities. Additionally, there are residential areas, road networks, and industrial activities, particularly those related to oil exploration, a key economic activity in the region (Townsvillages, 2025).

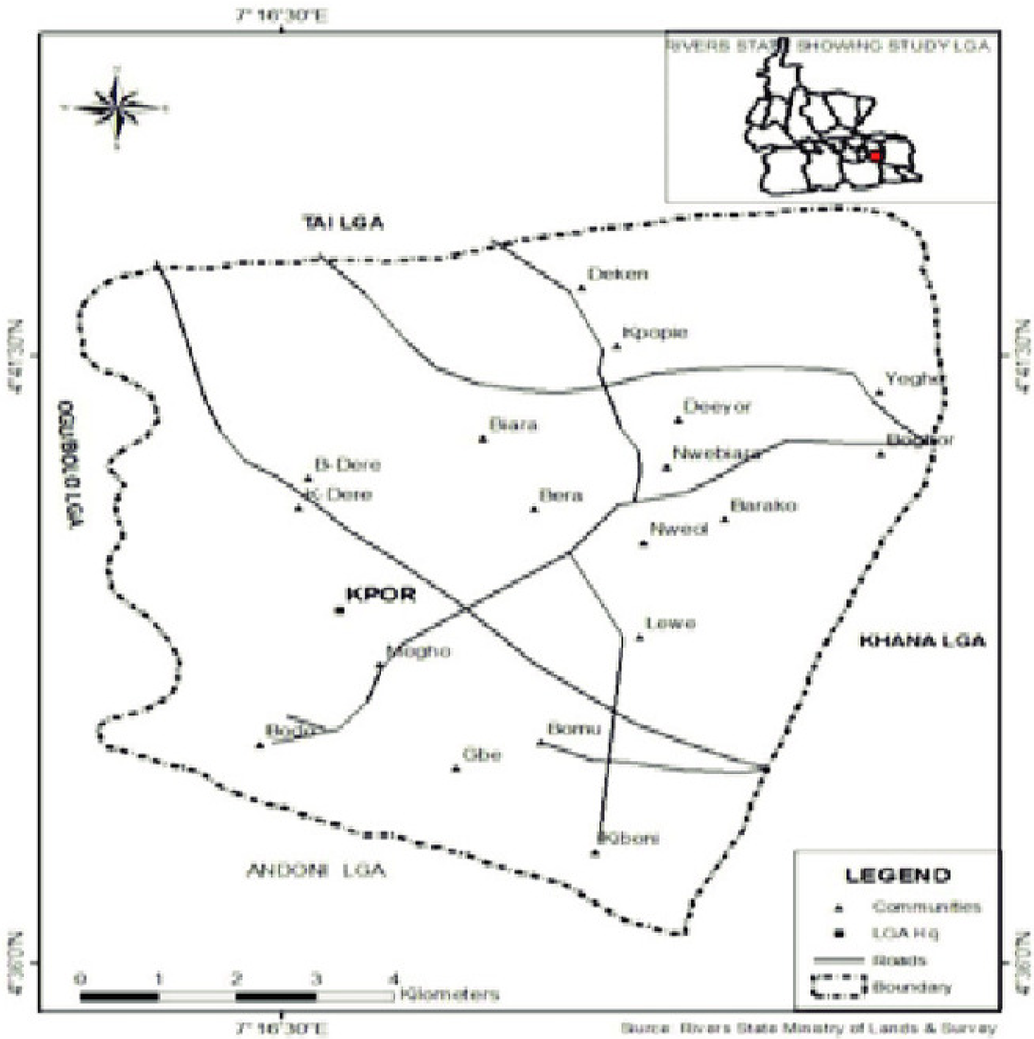

Fig. 1: Map of Gokana Local Government Area, showing B. Dere. (Government of Rivers State, Office of Surveyor General (2014)

Materials and Methods

Sample Collection and Frequency

Soil samples were collected at three different sampling points in B. Dere, Gokana Local Government Area, Rivers State, Nigeria. At each sampling point, a single soil sample was collected from two depth layers: 0–15 cm (first layer) and 15–30 cm (second layer) using a hand-held auger. Each sample weighed 50 g and was immediately stored in sterile cellophane bags, properly labeled, and transported to the laboratory for analysis. A non-contaminated soil sample, serving as the control, was collected from a garden in Rukporhokwu, Obio-Akpor L.G.A., Rivers State.

The sampling was conducted once during the study period to obtain representative soil samples for physicochemical analysis. The frequency of sample collection was not repeated over multiple time points, as the study aimed to assess the physicochemical properties of the soil at a specific time rather than monitoring temporal variations.

Experimental Design and Statistical Application

The experimental design directly influences the selection of appropriate statistical tools. Since the study involved comparing the physicochemical properties of contaminated and non-contaminated soils, descriptive and inferential statistical analyses were applied. The design allowed for statistical comparisons between depth layers and contamination levels.

Physicochemical Analyses

Physicochemical parameters were measured from soil samples using standard methods as described by the American Public Health Association (APHA, 1998) and the American Society for Testing and Materials (ASTM, 2003). pH and temperature were measured in a portable multi-probe quality meter (Model U7, Model-EXTECH, EC 500) while electrical conductivity (EC) was determined using electrical conductivity probe (Model-EXTECH II, 600). The instruments were calibrated using specific calibrating solutions. The soil samples were analyzed for nitrate and nitrite using a colorimetric method with an ultraviolet/visible HACH spectrophotometer. The quantification of phosphate content in soil samples was conducted using the ascorbic acid method as outlined in the APHA (2005) guidelines. The concentration of sulphate in the soil samples was measured using a turbidimetric method with an ultraviolet HACH spectrophotometer (HACH DR 3800 SC). Total Organic carbon was determined using the methodology of ASTM (2003) as modified by Gayathiri *et al.* (2017). The determination of total petroleum hydrocarbon (TPH) was conducted using a standardized protocol method of Chikere *et al.* (2019). Chloride content was determined by the Association of Official Analytical Chemists (1984) as modified by Ebe *et al.* (2017).

Data Analysis

The statistical analysis was done using the Principal Component Analysis (PCA) and Statistical Software Package for Social Sciences (SPSS) version 21.0 (SPSS, 2012).

RESULTS

Physicochemical Parameters of the Soil Samples

The temperature of the contaminated soil sample was 27.50±0.29 ^{0}C compared to the control which was 29.50±0.29 ^{0}C. The pH of the contaminated soil sample was 6.25±0.03 while the pH of the uncontaminated soil sample (control) was 6.15±0.15. The pH of the soils was acidic which is due to crude oil contamination. The electrical conductivity of contaminated soil (303.95±1.41 ɥscm^{-1}) significantly higher than the control (p<0.001) at 127.56±1.53 .The moisture (11.21±0.03), chloride(39.01±0.63 mg/L), nitrate (6.05±0.03 mg/L), nitrite (2.03±0.03 mg/L), phosphate (7.14±0.01 mg/L) , sulphate (84.06±0.00 mg/L) and TOC (18.81±0.05 %) contents of the contaminated soil sample were higher than the control soil samples with values for moisture (8.68±0.35), chloride (17.41±0.29 mg/L), nitrate (1.10±0.01 mg/L), nitrite (0.16±0.01 mg/L), phosphate (2.23±0.14 mg/L), sulphate (16.02±0.01 mg/L) and TOC (8.81±0.35 %) The concentrations of chloride, nitrite, nitrate phosphate and sulphate were significantly higher in the contaminated soils. In the contaminated soil, the percentage of TOC was significantly higher in contaminated soil than control (p<0.05). The TPH value at 27.90±0.45 mg/L was higher in contaminated soil than control with concentration of 12.84±0.02 mg/L. In the values of the particle size of silt, clay and sand in the control were higher (11.0±0.00, 21.50±0.29 and 60.00±0.00) than that of contaminated soil (7.5±0.29, 15.50±0.29 and 53.00±0.00) respectively.

Table 1: Physicochemical properties of soil samples

Parameters	**CS**	**NCS**
Temp (^{0}C)	27.50±0.29	29.50±0.29
pH	5.25±0.03^{aa}	6.15±0.15
EC (ɥscm^{-1})	303.95±1.41^{aa}	127.56±1.53
Moisture content	11.21±0.03	8.68±0.35
Chloride (mg/L)	39.01±0.63^{aa}	17.41±0.29
Nitrate(mg/L)	6.05±0.03^{aa}	1.10±0.01
Nitrite (mg/L)	2.03±0.03^{aa}	0.16±0.01
Phosphate(mg/L)	7.14±0.01^{aa}	2.23±0.14
Sulphate (mg/L)	84.06±0.00^{aa}	16.02±0.01
TOC (%)	18.81±0.05^{a}	8.81±0.35
Organic matter (%)	70.98±0.01^{aa}	15.24±0.15
TPH (mg/L)	27.90±0.45^{a}	12.84±0.02
Silt	7.5±0.29	11.0±0.00
Clay	15.50±0.29	21.50±0.29
Sand	53.00±0.00	60.00±0.00

Note: CS Contaminated soil, NCS = Non-contaminated soil, EC = Electrical conductivity; TOC = Total Organic Carbon; TPH = Total Petroleum Hydrocarbon, superscript (^{aa}) denotes significant difference, (^{a}) denotes slight difference.

The result of physicochemical analysis in contaminated soil on the abundance of soil microorganisms is shown in Fig. 1. Using the Principal component analysis (PCA), it was revealed that sulphate, TOC, organic matter, and sand were highly positively distributed thereby resulting to the rise of microorganisms while moisture content, chloride, clay were slightly positively distributed (P>1). The temperature, pH electrical conductivity, nitrate, nitrite, phosphate, THC and silt were negatively distributed, thereby affecting the abundance of microorganisms negatively (P<1). In figure 2, temperature, pH moisture content, phosphate and sulphate in the control were slightly positively distributed, electrical conductivity and sand were positively distributed affecting positively the abundance of microorganisms. The positive distribution of sand indicates that the soil is predominantly sandy (p>1). Chloride, nitrate, nitrite, TOC, organic matter and TPH, silt and clay were negatively distributed thereby influencing the abundance of microorganisms negatively (P<1). Figures 1 and 2 showed that the concentration of sulphate, chloride, TOC, organic matter and sand were more positively distributed than the concentration of sulphate, chloride, TOC, organic matter and sand in the contaminated soil than that of the non-contaminated soil. The nitrate, nitrite and phosphate contents are more in the contaminated soil than the non-contaminated soil.

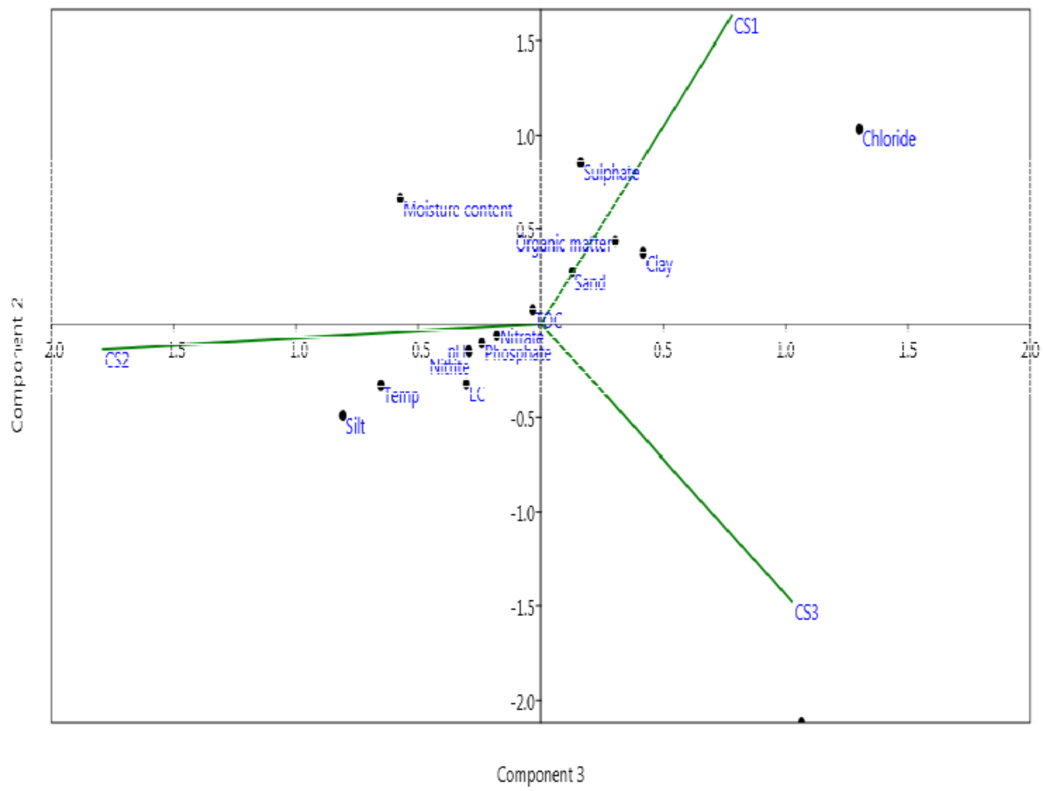

Fig. 1: The effect of physicochemical properties of contaminated soil sample using PCA on the abundance of soil microorganisms

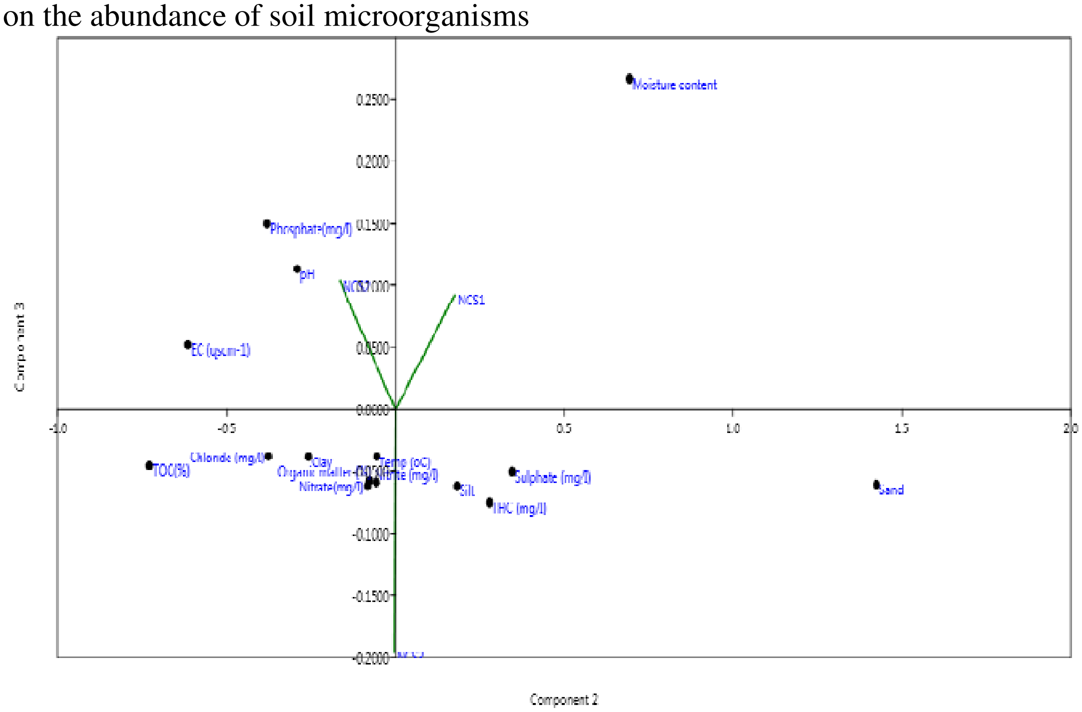

Fig. 2: The effect of the physicochemical properties of oil non-contaminated soil sample on abundance of soil microorganisms using PCA

DISCUSSION

Physicochemical properties of the soil identify the degree of contamination in impacted soils (Gayathiri *et al*., 2017) and also determine the exact amount of nutrients available to the soil (Joseph and Peter, 2020). Findings from this study correlated with the study of Gayathiri *et al.* (2017) that revealed that there was more concentration of nutrients in active soil (contaminated soil) than in the control (non- contaminated soil). The pH of the soils was acidic indicating there is presence of hydrocarbons in the contaminated soils in agreement with the study of Fatunla and Essien (2018) and Onwuka *et al*. (2021). In acidic soils, there is availability of macronutrients such as nitrogen, phosphorus, and sulphur. The temperature of the soils was in accordance with the optimum temperature (25°C to 30°C) for microbial growth. Temperature is the most important factor to determine the survival of microorganisms according to Gayathiri *et al.* (2017). The temperature of the control was higher indicating higher rate of speed of microbial degradation than the contaminated soil. The electrical conductivity of crude oil consists of petroleum hydrocarbons which possess huge count of iron in the soil which could bound with the existing ions in the soil. Therefore, the EC of the contaminated soil increased due to increase in contamination in agreement with the study of Rabenberg and Kniffen (2014). EC reflects the sum of salts and iron in the soil, the physical structure and health of the soil to measure crop productivity. As EC increases there is need for more attention in soil management in order to prevent salinity from adversely affecting plants. The higher moisture in the control increases plant growth than in the contaminated soil.

The total petroleum hydrocarbon (TPH) higher in the contaminated soil indicates that oil activity has negative impact on the soil which was previously reported by Igwe *et al.* (2021). The total hydrocarbon content (THC) in the soil generally accounts for the microbial biomass (Igwe *et al.,* 2021). The total organic carbon in the soil increased due to contamination, which in turn decreases microbial growth, resulting in the decrease in nitrate, nitrite and phosphorus concentrations in the soil. The carbon-hydrogen mixture of petroleum hydrocarbons caused by oil spill in the soil upset the C-N balance. Therefore, for effective metabolism, growth and development of microorganisms in the soil, a relatively high C-N ratio and a C-P ratio are ideal (Girigiri *et al.,* 2019). Organic matter contains carbon compounds that are formed by the microorganisms (Ssenku *et al*., 2022). Microorganisms decompose this organic matter which results to the release of nutrients which are taken up by plant roots.

Plants take up chloride as Cl^- ions from soil solutions. This help play a role in osmotic adjustment and suppression of plant diseases. Particle size composition revealed that the soil was sandy in nature, and this helps infiltration of contaminants and thereby increases the pollution pathway for contamination. The texture allows free drainage and cause mobility of ions within the soil. Soil texture makes up the mineral fraction of the soil in clay. Light soils are higher in sand while heavy soils are higher in clay. This study revealed that the soil is light since it contains higher sand than clay which is in accordance with the research done by Gayathiri *et al*. (2017).

CONCLUSION

Crude oil contamination has the potential to reduce the health and quality of soil thereby resulting to low agricultural productivity and hence affecting the source of income negatively reducing the source of livelihood in B-dere Community in Gokana Local Government Area, Rivers State, Nigeria.

RECOMMENDATIONS

It is highly recommended that measures should be put in place for prevention of increase of crude oil contamination.

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