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## Effect of Crude Oil Contamination and Bioremediation with Fertilizer on Physicochemical Properties of Soil

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**ABSTRACT:** The release of hydrocarbons into the environment whether accidentally or through human activities is a main cause of water and soil pollution. This study investigated the effect of crude oil contamination and fertilizer treatment on soil physicochemical properties. Unpolluted soil samples obtained from the bed of Ovia River, Benin City, Nigeria, were contaminated with crude oil, and thereafter remediated with NPK/urea fertilizer. A range of physicochemical parameters were measured in both soil samples. The results showed that electrical conductivity, moisture content, water holding capacity, total nitrogen content and available phosphorus were significantly higher in contaminated clay soil than in sandy-clay soil, while bulk density, porosity and pH were higher in contaminated sandy-clay soil than in clay soil ( $p < 0.05$ ). After 36 days bioremediation of the contaminated clay/sandy-clay soils with NPK/urea fertilizers, the results followed the same trend. Crude oil-contamination and fertilizer treatment significantly and concentration-dependently increased organic matter of both soils but it did not significantly alter total petroleum hydrocarbon (TPH) content. In addition, crude oil-contamination of clay/sandy-clay soil markedly increased the TPH, but it was significantly and concentration-dependently reduced by fertilizer treatment. These results indicate that bioremediation strategy that employs fertilizer may be useful for restoring soil fertility after an episode of crude oil contamination.

**Keywords:** Contamination, Crude oil, Fertilizers, Physicochemical parameters, Soil.

### Introduction

Soil is one of the most important resources of nature on which plants grow. As a component of terrestrial ecosystem, soil is not only important for agriculture but also for living organisms (Nwachokor *et al.*, 2009). The importance of soil as a reservoir of nutrients and moisture for the production of forage and plant species has long been recognized (Schlesinger, 1990). Vegetation distribution and development largely depends on soil condition (Kardol *et al.*, 2006). Understanding of soil chemical reaction and processes is essential for developing innovative resource management strategies (Shirbhate and Malode, 2012). Modern concept of soil quality refers to the ability to sustain plant and animal productivity, to increase water and air quality and to contribute plant and animal health. Soil health and quality has consistently evolved with an increase in the understanding of soil and soil quality attributes (Chaudhary *et al.*, 2012). Knowledge of the characteristics of a soil is essential for developing optimum land use plan for maximizing agricultural production (Kumar *et al.*, 2013; Singh and Rathore, 2013).

During crude oil exploration, production, refining, transport and storage, leaks and accidental spills occur. Such oil spillage is a major cause of water and soil pollution (Das and Mukherjee, 2011). The release of hydrocarbons into the environment whether accidentally or through human activities is a main cause of water and soil pollution. Soil contamination with hydrocarbons causes extensive damage of local systems (accumulation of pollutants in animal and plant tissues may cause death or mutations). Crude oil spills have been demonstrated to negatively impact the physicochemical properties of soils.

## Materials and methods

**Chemicals/reagents:** The chemicals and reagents used in this study were of analytical grade. They were products of Sigma-Aldrich Limited (UK).

**Collection of soil samples:** The crude oil used in this study was obtained from Shell Petroleum Limited, Jala, Warri South Local Government Area, Delta state, Nigeria. The unpolluted soil samples were obtained from the bed of Ovia River, Unuamen, Ovia North-East Local Government Area, Edo state, Nigeria. The soil samples bagged in a clean container were transported to the Department of Soil Science, Faculty of Agriculture, University of Benin, Benin City, Edo State, for textural classification. Textural classification of the soils showed that the clay soil contained 77 % clay, while that of the sandy-clay soil was 72 %.

**Experimental design:** The unpolluted soil samples were contaminated with crude oil at varied concentrations, and thereafter remediated with NPK/urea fertilizer after 36 days.

### Assessment of soil physicochemical properties

**Measurement of soil temperature:** A pilot hole was bored on the soil using a screw driver in order to prevent the thermometer from breaking when pushing it hard into the soil. A thermometer was then fixed into the soil tightly to measure the soil temperature (Hursh *et al.*, 2017). Soil temperature was obtained on the site between 8 to 9 am.

**Determination of pH of soil:** Deionized water (10 mL) was added to 10 g of air-dried soil weighed in a 25 mL beaker, and mixed thoroughly for 5 s with a glass rod. The soil suspension was allowed to stand for 30 min. The pH of the soil was measured using pH meter. The pH was determined quickly to the next 0.1 pH unit (McLean, 1982).

**Measurement of bulk density:** A weighing balance was used to weigh an empty universal bottle, which was thereafter filled with oven-dried soil sample. The bottle filled with oven-dried soil sample was weighed and then emptied; and the volume was then determined using a burette (FAO, 1980).

$$\text{Soil Bulk Density (g/cm}^3\text{)} = \frac{\text{Weight of oven dry Soil}}{\text{Volume of Soil}}$$

**Determination of soil moisture content:** Soil moisture content was determined using gravimetric method. It is used to find out the mass difference when wet soil sample is subjected to oven drying at a temperature of 105 °C. A mass  $M_1$  g was recorded when an empty crucible was weighed. A mass  $M_2$  g was obtained and recorded when wet soil sample was placed in the crucible and weighed quickly using a weighing balance. The crucible containing wet soil sample was put in an oven and dried to constant weight at 105 °C. The sample was thereafter put in a desiccator to cool. A mass  $M_3$  g was obtained and recorded immediately after the crucible with the oven-dried soil was weighed.

$$\text{Moisture Content (\%)} = \frac{(M_2 - M_3) \times 100}{M_3 - M_1}$$

where:  $M_1$  = Mass of empty crucible

$M_2$  = Mass of crucible and wet soil

$M_3$  = Mass of crucible and oven-dried soil

**Evaluation of water holding capacity of soil:** A small cup with little holes at the bottom was weighed and then recorded. A filter paper was positioned at the foot of the cup and the weight was obtained. Exactly 70 g of soil sample was weighed into the cup. The cup was then clamped to a retort stand, while a measuring cylinder of 250 mL with funnel inserted into it was positioned under it. Deionized water (50 mL) was added and allowed to drain overnight. The drained water was read and recorded (FAO, 1980).

$$\text{WHC} = \frac{\text{Volume of Water Retained}}{\text{Volume of Sample}} \times 100$$

**Measurement of soil porosity:** Air-dried soil sample (50 g) was put in a 500 mL measuring cylinder and 100 mL of deionized water was gently and slowly added until it reached the top of the soil. The volume of water used was accurately recorded (FAO, 1980).

$$\text{Porosity} = \frac{\text{Amount of Water Added to Soil Sample} \times 100}{\text{Total Soil Sample}}$$

**Determination of particle size distribution:** Exactly 880 mL deionized water together with 100 mL of 5 % dispersing solution were mixed in 1000 mL cylinder (880 mL + 100 mL = 980 mL, was the blanked mixture which was not diluted to 1000 mL). Exactly 50 g of the soil occupied a volume of 200 mL. The weight of the 50 g soil was obtained after it was transferred to a dispersing cup. Exactly 100 mL of 5 % dispersing cup was attached to the mixer to mix sample for 30 – 60 s. A large amount of the suspension was transferred from the dispersing cup to 1000 mL measuring cylinder and deionized water was then added to take the volume of the mark so as to balance the room temperature. The temperature at the start of each set/hydrometer reading of the

blank was determined thus: The plunger was immersed into the suspension and mixed for 30 s till the suspension was uniform to determine the density. The hydrometer was inserted into the suspension following the plunger removal, and this was timed for 40 s. The hydrometer reading represented the quantity of clay and sandy-clay soils in the suspension. The clay and sandy-clay soils were then allowed to settle to the bottom of the cylinder at this time. The experiment was repeated for each sample, and hydrometer readings were recorded after 6 h, 52 min: this represented the quantity of clay soil in suspension, and at this time also the sandy-clay soil had stabilized in the bottom of the cylinder.

*Determination of electrical conductivity of soil:* Air-dried soil (10 g) was weighed into a bottle and mixed with water to make a suspension. Deionized water (50 mL) was added and agitated manually at 15 rpm for 1 h to dissolve insoluble salts. Following the producer's directives, the conductivity meter was calibrated with potassium chloride (KCl) reference solution to get the cell constant. The cell was completely rinsed, and the electrical conductivity of 0.01 M KCl was measured at equal temperature of the soil suspensions. The conductivity meter was rinsed with the soil suspension and then refilled with unagitated and settled soil. The meter readings were then recorded. The cell was cleaned with deionized water between samples (Miller and Curtin, 2006).

$$\text{Electrical Conductivity (EC)} = \frac{S \times 1.413}{K}$$

where: S = Measured resistance of suspension

K = Measured resistance of KCl solution

*Determination of total nitrogen in soil:* Soil (2 g) was weighed into 500 mL Kjeldahl digestion flask and then mixed with distilled water (10 mL). Both the Kjeldahl catalyst mixture and 15 mL of 18.6 M tetraoxosulphate (VI) acid (H<sub>2</sub>SO<sub>4</sub>) were added. The flask was carefully heated until the bubbles stopped. Heating rises till digestion of the mixture was completely clear. Heating continued for another 1 h after which the flask was allowed to cool and distilled water was gently added and agitated. Granulated zinc of about three chips were supplemented and 30 mL of boric acid was added into 250 mL conical flask and positioned under a condenser. Exactly 75 mL of 10 M sodium hydroxide (NaOH) was gently added into the digest in Kjeldahl flask and quickly fixed to distillation apparatus. The ammonia (NH<sub>3</sub>) evolved and the distillate was subsequently titrated with standardized acid along with four drops of mixed indicator (FAO, 1980).

$$\text{Total Nitrogen (\%N)} = \frac{(\text{Equivalents of acid added to sample} - \text{equivalents of acid added to blank}) (14.01) (100)}{\text{Sample weight (g)}}$$

*Determination of available phosphorus in soil:* Air-dried soil sample (2.5 g) was weighed and put in a neat and dried 125 mL polyethylene bottle. Exactly 50 mL of 0.5 M sodium bicarbonate (pH 8.0) with polyacrylamide was supplemented as the extracting solution from a dispenser. The glass bottles were put in a reciprocating shaker and shaken for about 30 min. The filtrate was filtered into the test tube using filter paper. The available phosphorus in clear filtrate was then determined using technicon II auto-analyzer.

$$\text{Soil P (mg/kg)} = \frac{A \times B \times C \times M}{E}$$

where: EA = Sample extract reading (mg l<sup>-1</sup>)

B = Extract volume (mL)

C = Dilution, if performed

M = Moisture correction factor

E = Sample weight (g)

*Determination of soil total organic carbon:* Soil sample suspension (0.1 mL) was put in 50 mL polypropylene centrifuge tube separately. Two soil samples of different types were prepared and then labelled blank. Exactly 5 mL of 1N HCl was added to the three duplicates, [the two standard samples and the polypropylene centrifuge tube labeled as blank (the blank was devoid of soil)]. The centrifuge tubes containing soil and HCl solution was energetically shaken manually for 10 s at 1 min interval for 5 min. Each centrifuge tube contained 25 mL of solution. To the 10 mL solution in syringe, 10 mL of liquid was added and 0.45 μm polycarbonate syringe filter was then attached. A filter opening was positioned above a neat 1 cm methacrylate cuvette and carefully pressed to force the extract via the filter into the cuvette. A wipe was used to clean the dirt on the cuvette and the finger prints was used to prevent a light beam from going through the cuvette and filtrate. The filtrate sample was then put in H, which is the UV-V instrument used to measure the organic carbon of the soil and the result was recorded.

*Determination of total petroleum hydrocarbon:* Soil sample (5 g) was completely mixed with anhydrous sodium sulphate of 5g in Vial. n-hexane of 15 mL was added and vortexed for 10 min and was capped tightly later. 0.45 μm Teflon filter was then used to filter the resulting soil suspension. Gas Chromatography with Flame Ionization Detector (GC-FID) GC-FID (HP 7890) was then used to analyze the filtrate. The temperatures of the injectors and detector were at 250°C and 350°C respectively. The temperature of the oven was maintained

initially at 5°C/min to 280°C and held for 6min. The volume of the injection for both standards and samples was 1µL (Chaineau *et al.*, 2005)

*Data analysis:* Data are presented as mean ± standard error of mean (SEM). Student's *t* test was used to compare means between the two sample groups. The data analyses were performed using SPSS version 23. Values of *p* < 0.05 were considered statistically significant.

## Results

*Physicochemical characteristics of the soil samples:* Results of the comparative studies of physical and chemical properties for both clay and sandy-clay soils using standard analytical methods are presented in Tables 1 and 2. The textural classifications of the soils were clay soil with percentage composition of 77 % and sandy-clay soil with percentage composition of 72 %. Parameters like pH, total nitrogen, available phosphorus, potassium, total organic carbon, total petroleum hydrocarbon, moisture content, soil bulk density, electrical conductivity, porosity, water holding capacity and temperature were analyzed in both clay and sandy-clay soils.

The physicochemical parameters such as electrical conductivity, moisture content, water holding capacity, total nitrogen content and available phosphorus were significantly higher in contaminated clay soil than in sandy-clay soil, while bulk density, porosity and pH were higher in contaminated sandy-clay soil than in clay soil (*p* < 0.05). These results are presented in Table 1. At the end of 36 days bioremediation of the contaminated clay and sandy-clay soils with NPK and urea fertilizers, the results followed the same trend (*p* < 0.05; Table 2). Contamination with crude oil and fertilizer treatment significantly and concentration-dependently increased the organic matter content of both soils but it did not significantly alter the TPH content. In addition, crude oil contamination of clay/sandy-clay soil markedly increased the TPH content, but it was significantly and concentration-dependently reduced by fertilizer treatment. It is likely NPK/urea fertilizer can degrade some crude oil components.

**Table 1** Comparison of physicochemical properties between clay and sandy-clay soils contaminated with crude oil

Parameters	Clay Soil Contaminated Sample				Sandy-clay Soil contaminated Sample			
	Control	3000 ppm	5000 ppm	8000 ppm	Control	3000 ppm	5000 ppm	8000 ppm
pH	6.74 ± 0.05	5.60 ± 0.01	5.50 ± 0.04	5.70 ± 0.03	6.32 ± 0.30	6.50 ± 0.12	6.30 ± 0.35	6.70 ± 0.64
Total Nitrogen (mg/kg)	0.50 ± 0.00	0.19 ± 0.02	0.21 ± 0.01	0.26 ± 0.50	0.42 ± 0.77	0.16 ± 0.50	0.21 ± 0.10	0.22 ± 0.10
Available Phosphorus (mg/kg)	7.20 ± 2.36	4.41 ± 1.10	4.47 ± 1.14	4.54 ± 2.10	6.20 ± 2.07	3.41 ± 1.26	3.49 ± 1.31	3.54 ± 1.20
TOC (%)	0.067 ± 0.4	0.10 ± 0.02	0.21 ± 0.20	0.42 ± 0.12	0.07 ± 0.17	0.10 ± 0.12	0.28 ± 0.02	0.43 ± 0.18
Potassium	8.89 ± 2.02	6.54 ± 1.99	6.58 ± 1.53	6.62 ± 1.32	6.91 ± 1.67	4.54 ± 1.10	4.56 ± 1.20	4.58 ± 1.42
TPH(mg/kg)	< 1	7568	7601	7608	< 1	7568	7601	7608
Moisture Content (%)	0.31 ± 0.03	0.31 ± 0.04	0.73 ± 0.02	1.32 ± 0.04	0.24 ± 0.09	0.27 ± 0.01	0.68 ± 0.04	1.28 ± 0.05
Soil bulk density (g/cm <sup>3</sup> )	1.08 ± 0.02	2.86 ± 0.13	2.93 ± 0.14	2.01 ± 0.99	1.69 ± 0.77	2.79 ± 0.22	3.95 ± 0.30	4.07 ± 0.69
Conductivity (µs/cm)	1.80 ± 3.2	1.90 ± 2.86	1.70 ± 1.98	1.90 ± 2.56	1.60 ± 2.30	1.70 ± 2.02	1.50 ± 1.88	1.70 ± 1.78
Porosity	0.52 ± 0.03	0.36 ± 0.06	0.30 ± 0.04	0.28 ± 0.08	0.30 ± 0.02	0.32 ± 0.02	0.35 ± 0.09	0.38 ± 0.08
Water Holding Capacity	0.18 ± 0.00	0.18 ± 0.01	0.18 ± 0.01	1.18 ± 0.01	0.16 ± 0.04	0.16 ± 0.03	0.16 ± 0.04	0.16 ± 0.33
Temperature	27°C							
Particle Size Distribution								
• Clay Soil (%)	77							
• Sandy Clay Soil (%)	72							

Values are mean ± SEM (n = 3)

**Table 2:** Comparison of Physicochemical Properties between Contaminated Clay Soil and Sandy-clay Soil Treated with NPK 15:15:15 and Urea Fertilizers

Parameters	Treated clay Soil			Treated sandy-clay soil		
	3000 ppm	5000 ppm	8000 ppm	3000 ppm	5000 ppm	8000 ppm
pH	5.68 ± 0.32	6.19 ± 0.32	6.45 ± 0.10	8.35 ± 0.22	8.29 ± 0.18	8.45 ± 0.22
Total Nitrogen (mg/kg)	0.32 ± 0.01	0.36 ± 0.04	0.41 ± 0.02	0.27 ± 0.12	0.30 ± 0.11	0.38 ± 0.23
Available Phosphorus (mg/kg)	6.20 ± 1.08	6.37 ± 1.22	6.76 ± 1.33	5.15 ± 0.99	5.34 ± 0.88	5.73 ± 0.90
TOC%	1.25 ± 0.20	2.03 ± 0.11	4.49 ± 0.30	1.27 ± 0.23	2.01 ± 0.21	4.49 ± 0.30
Potassium	72.30 ± 4.01	73.40 ± 3.80	74.7 ± 3.15	70.70 ± 2.11	71.30 ± 2.01	72.20 ± 1.85
TPH (Mg/Kg)	633.00 ± 3.01	620.00 ± 3.40	541 ± 3.44	635.00 ± 3.10	618.00 ± 2.44	542.00 ± 3.64
Moisture Content (%)	3.80 ± 0.34	3.94.00 ± 0.22	4.01 ± 0.32	3.78 ± 0.44	3.89 ± 0.13	3.99 ± 0.13
Soil bulk Density (g/cm <sup>3</sup> )	3.18 ± 0.11	3.29 ± 0.21	3.38 ± 0.13	3.73 ± 0.20	3.88 ± 0.22	3.95 ± 0.33
Conductivity (μs/cm)	225.00 ± 4.20	205.00 ± 3.90	227.00 ± 3.92	215.00 ± 3.01	200.00 ± 3.40	212.00 ± 3.05
Porosity	0.22 ± 0.01	0.35 ± 0.02	0.38 ± 0.01	0.40 ± 0.04	0.42 ± 0.02	0.44 ± 0.01
Water Holding Capacity	1.25 ± 0.14	1.25 ± 0.56	1.27 ± 0.42	1.23 ± 0.33	1.23 ± 0.31	1.25 ± 0.42
Temperature e	27°C					
Particle Size Distribution						
Clay Soil (%)	77					
Sandy Clay Soil (%)	72					

Values are mean ± SEM (n = 3)

## Discussion

Soil is a complex matter and comprises minerals, organic matter, water, and air. These fractions greatly influence soil texture, structure, and porosity. These properties subsequently affect air and water movement in soil layers, and thus the soil's ability to function. Therefore, soil physicochemical properties have great influence on soil quality. Soil texture especially can have profound effect on many other properties. Thus, soil texture is considered one of the most important physical properties of soil. In fact, soil texture is a complex fraction, consisting of three mineral particles: sand, silt, and clay. These particles vary by size and make up the fine mineral fraction. Generally, the coarse mineral fraction, which consists of particles over 2 mm in diameter, is not considered in texture. But in some cases they may affect soil physicochemical properties such as water retention. Textural categorization of a soil is decided by the relative amount of various particle sizes, that is, whether it is clay, loam, or sandy loam.

All agricultural productions and development of forest depend on physicochemical parameters of the soil. Soil quality analysis includes an analysis of parameters and processes which enable soil to operate efficiently as component of a sound ecosystem (Tale and Ingole, 2015). Soil quality includes a capacity for water retention, carbon sequestration, plant productivity, waste remediation, and other functions (Prakash, 2014). The development of the concept of land quality, explores the use of soil chemical and physical attributes as determinants of soil quality (Shivanna and Nagendrappa, 2014; Mobar, 2015).

The most significant property of soil is its pH, since it affects all other parameters. It influences solute concentration and adsorption (Akpoveta *et al.*, 2010). Therefore, pH is considered while analyzing any kind of soil. If the pH is less than 6 then it is said to be an acidic soil, the pH range from 6.0 - 8.5 it is a normal soil, and greater than 8.5 then it is said to be alkaline soil. Soil pH is an important consideration in agriculture as many plants and soil life forms prefer either alkaline or acidic condition (Pandeewari and Kalaiarasu, 2012). It is a good indicator of balance of available nutrients in the soil. It also help in maintaining soil fertility and to quantify the amendments used for amelioration (Solanki and Chavda, 2012). Studies have shown that high pH of soil can affect the micronutrients content. At low pH values solubility of micronutrients is high while at high pH solubility and availability of micronutrient to plant is declined (Patel, 2014). In general, soil pH increase with depth. Extremely high and low pH often lead to failure of crop due to ionic strength imbalance (Elango *et al.*, 1992). In this study, the high pH of contaminated/ treated sandy-clay soil could be attributed to leakage and spread of alkaline effluent generated from the crude oil contaminant, as it is well know that high sodium content gives rise to high pH in the soil (Kumar *et al.*, 2011). Soil infiltration problem is also associated with high pH.

Nitrogen, the most critical element obtained by plants from the soil, is a necessary requirement for plant growth (constituent of chlorophyll, plant protein and nucleic acid). Accounting for 80 % of atmospheric gas, nitrogen diffuses into water where it can be fixed by blue-green algae. As the most important fertilizer element, plant roots take up nitrogen in the form of NO<sub>3</sub> and NH<sub>4</sub> (Sun *et al.*, 2013). As the most important major nutrient required by plant for proper growth and development, nitrogen is part of all living cells (Singh and Rathore, 2013). Nitrogen cycle plays an important role in soil system, and it is influenced by biological processes (Jain *et*

*al.*, 2014). Soil nitrogen is also directly related to soil organic carbon (Singh and Negi, 2013). Nitrogen influences the quality of plant fruits, and it increases the fruits protein content. Supply of nitrogen either through organic and inorganic sources also plays an important role for higher winter sorghum productivity in addition to the moisture conservation (Pujar *et al.*, 2012). The lower value of total nitrogen in organic plots could be as a result of crop uptake, immobilization by microorganisms and its loss through volatilization (Defoer *et al.*, 2000). The results of this study showed that total nitrogen content was significantly higher in contaminated clay soil than in sandy-clay soil, but it was higher in treated sandy-clay soil than in treated clay soil. In a previous study, it was reported that inorganic fertilizer-treated soil showed higher nitrogen content. It has also been demonstrated that the availability of nitrogen and its different forms decreased with increase in soil depth. Soil acidification is the major problem faced by farmers due to excessive use of inorganic nitrogen fertilizers in agriculture.

Phosphorus is one of the most important micronutrient essential for plant growth (Jain *et al.*, 2014). It is also crucial for photosynthesis, participating in the formation of oils, sugars, starches, amongst others (Singh and Rathore, 2013). Phosphorus is necessary for seed germination, flowering and fruits formation; its deficiency symptoms are purple stem/leaves, and poor yield of fruit (Wagh and Sayyed, 2013a). It is necessary for maintaining a balance between the other plant nutrients and ensuring normal growth of crops (Wagh *et al.*, 2013b). Activities of plant such as growth, respiration and reproduction depend on phosphorus levels of the soil (Wagh *et al.*, 2013b). In this study, available phosphorus was significantly higher in contaminated clay soil than in sandy-clay soil, as well as in treated clay soil than in sandy-clay soil. These results are in agreement with those of previous reports (Elango *et al.*, 1992; Singh and Rathore, 2013). Soil with high organic matter has been demonstrated to have better supplies of organic phosphate for plant uptake than those with low organic content (Miller and Donahue, 2001). Adequate phosphorus availability for plants stimulates early plant growth and hastens maturity (Solanki and Chavda, 2012). Soils with minimum leaching are known to contain high amount of phosphorus as compared to those with maximum leaching (Ashraf *et al.*, 2012).

Organic matter is an important property of soil. Soil poor in organic matter is always prone to erosion. Organic matter may be added to soil in the form of animal/green leaf manures, and compost. High soil organic matter content could be responsible for lowered pH (Hodes, 1996). Soil organic matter content decreases from surface to subsoil due to leveling (Helburg *et al.*, 1978). Increase in the rate of decomposition of organic matter supports maximum plant growth. Organic matter commonly increases water content at field capacity, water-holding capacity available water content in sandy soil and both air and water flows rates through fine textured soil as well as absorb cations (Ramulu, 2001; Amos-Tautua *et al.*, 2014). It also functions as a source of food for soil microbes thus enhancing their activity (Brady, 1996). The results of this study showed that contamination with crude oil and fertilizer treatment significantly and concentration-dependently increased the organic matter content of both soils.

Potassium is not an integral part of any major plant component but it plays a key role in a vast array of physiological processes vital to plant growth from protein synthesis to maintenance of plant water balance (Sumithra *et al.*, 2013). It is involved in a number of plant metabolic reactions, ranging from lignin and cellulose (used for formation of cellular structural components) to regulation of photosynthesis/production of plant sugars (Solanki and Chavda, 2012). Found in its mineral form potassium affects plant cell division, carbohydrate formation, translocation of sugar, various enzyme action and resistance to certain plant diseases (Jain *et al.*, 2014). The high content of available potassium on surface soil may be attributed to the application of potassium fertilizers and manures (Miles and Hammer, 1989). Potassium fixation occurs when soil dries up and the potassium is bound between layers of clay (Wagh *et al.*, 2013). Its concentration decreases with increase in depth of soil. Soils that have adequate potassium allow plants to develop rapidly and outgrow plant disease, insect damage and protect against winter freeze damage (Solanki and Chavda, 2012). Potassium is necessary for balancing nitrogen levels. It is required by plants in larger amounts than any other mineral element except nitrogen and in some cases, calcium (Singh *et al.*, 2013). Water loss from plants is controlled by potassium. A study showed that increase in potassium availability in Kaolinitic soil increased the grain yield of winter sorghum as reported by Pal.

Total petroleum hydrocarbon (TPH) describes the overall amount of petroleum-based hydrocarbons present in a sample (soil, water, sediment, or air). Total petroleum hydrocarbon (TPH) is commonly measured to assess environmental pollution from oil spills or leaks; monitor contaminated sites, evaluate health and environmental risks; and guide cleanup and remediation efforts. In this study, crude oil contamination of clay/sandy-clay soil markedly increased the TPH. It is likely NPK/urea fertilizers can degrade some crude oil components. In this study, fertilizer treatment did not significantly alter the TPH content.

Moisture is a most important physical property of soil. Absorption of nutrients depends on moisture of the soil. The water content of soil is also much related to its texture and structure. Soil moisture commonly depends on void ratio, particle size, clay minerals, organic matter and ground water condition (Yennawar *et al.*, 2013). Wetness depends largely on the porosity of a soil, and for that reason clayey soil, which have high porosity

generally have larger water content than do sandy soils (Williams, 2005). Good water-holding capacity shows that a soil is in a good physical condition. Knowledge of soil water holding capacity is essential to the evaluation of regional soil water balance (Vanderlinden *et al.*, 2005). Thakare *et al* reported maximum water holding capacity for red and black soils (Thakre *et al.*, 2012). Decomposition of organic matter is mainly dependent on soil moisture. In this study, moisture content was significantly higher in contaminated/treated clay soil than in sandy-clay soil, and agrees with those of previous studies (Oseni *et al.*, 2009; Jain and Singh, 2014). Soil bulk density (SBD) is a measure of how compact the soil is (how tightly soil particles are packed together). It shows the mass of dry soil per unit volume, including the spaces between soil particles (pore spaces). Soil bulk density affects root growth (high density = harder for roots to penetrate), water infiltration and drainage; soil aeration (oxygen availability); and soil fertility and microbial activity. Factors that affect bulk density include soil texture (sand > silt > clay), organic matter content (more organic matter = lower bulk density), compaction from machinery or foot traffic, and tillage practices. In this study, bulk density was markedly higher in contaminated/treated sandy-clay soil than in clay soil.

Electrical conductivity is a very quick, simple and inexpensive method to check the health of soils. It is a measure of ions present in solution. Electrical conductivity of a soil solution increases with increased concentration of ions. It varies with depth and its range of variation is less in upland profile, probably due to slope of land surface, high permeability and high rainfall (responsible for leaching out alkali and alkaline bases) (Dutta and Ram, 1993). It is a measurement that correlates with soil properties that affect soil texture, cation exchange capacity, drainage condition, organic matter level, salinity and subsoil characteristics (Solanki and Chavda, 2012). Commonly used as a measure of salinity, electrical conductivity estimates soluble salt/ nutrients concentrations in soil (Smith and Doran, 1996). Electrical conductivity of soils varies depending on the amount of moisture held by soil particles. It is useful for monitoring the mineralization of organic matter in soil (De-Neve *et al.*, 2000). Electrical conductivity < 1 (dS/cm) = normal soil; 1 – 2 (dS/cm) = critical for germination; 2 – 3 (dS/cm) = critical for growth of salt sensitive crops; and > 3 (dS/cm) = severely injurious to crops (Deshmukh, 2012). The results of this study showed that electrical conductivity was significantly higher in contaminated/treated clay soil than in sandy-clay soil, and are consistent with those of previous reports (Putman and Alt, 1987; Wagh, *et al.*, 2013b).

Porosity is the percentage of total soil volume that is made up of pore spaces (voids) (tiny gaps between soil particles), rather than solid particles. These pores which may be filled with air or water, are essential for plant growth and soil health. Soil pores are either macro- or micropores. High porosity means more pore space, while low porosity refers to fewer pores. Water-holding capacity (WHC) of soil refers to the ability of soil to retain water against the force of gravity and make it available for plant use. It represents the maximum amount of water a soil can hold in its pore spaces after excess gravitational water has drained away. Soil water exist in different forms: gravitational, capillary, hygroscopic water. The results of this study showed that porosity values were significantly higher in contaminated/treated sandy-clay soil than in clay soil.

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