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Effects of Crude Oil Contamination on Soil Physical and Chemical Properties and some Growth Parameters and Yield of Okra (*Abelmoschus esculentus)*

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ABSTRACT
This study was conducted at Delta Steel Company, Technical High School Farm in Udu local Government area, to examine the effects of crude oil contamination on soil physicochemical properties and growth parameters and yield of okra. Top soil of 3kg samples were measured into 16 poly bags. Crude oil was used to contaminate the soils at the rate of 0, 37.5, 75 and 112.5ml per pot arranged in a completely randomized designed and replicated three times. The growth parameters taken were seed emergence, plant height, stem girth and fruits yield of okra. Soil physicochemicals parameters measured were particle size distribution, bulk density, total porosity, hydraulic conductivity, soil pH, organic carbon, total nitrogen, available phosphorus and exchangeable bases. Data collected were subjected to Analysis of Variance and means were separated using Least Significant Difference (LSD). The available phosphorus ranged from 1.56–3.59, exchangeable bases Ca, Mg, K and N ranged from 2.34-2.81, 1.79-1.87, 1.48-1.56 and 1.12-1.38 respectively decreased with increase in levels of oil contamination while pH, Total nitrogen and organic carbon were significantly enhanced. Conclusively crude oil contamination decreased some growth parameters and fruits yield of okra and total porosity, moisture content, hydraulic conductivity, available phosphorus, exchangeable bases and also enhanced the bulk density, total nitrogen and organic carbon.
Keywords: crude oil, *Abelmoschus esculentus*, seed emergence, plant height, stem girth and fruit yield.

INTRODUCTION

Crude is unrefined oil found underground primarily composed of a complex mixture of hydrocarbons, metals and organic compounds (Ohanmu *et al*., 2014). As the primary source of energy in the worldwide, crude oil plays a vital role in the global economy (Walter and Silliker, 2016). In Nigeria, crude oil is crucial for revenue generation and development (Ohanmu *et al*., 2014). It is estimated that 80% of crude oil pollution is caused by spills which are a major environmental concern in Nigeria (Odu, 1997). Oil spillage affects crop yield, farm income and by extension the social and economic livelihoods of farming communities (Abosede, 2013), thus affecting the quality of human life, productivity in plant yield, survivals of animals and microbes populace.

The contamination of the environment (mainly terrestrial and aquatic) by crude oil is alarming and this has raised considerable concern on the subject of crude oil pollution especially on arable agricultural land. (Chukuwmati and Abams, 2021). Oil pollution in the environment has been a major source of concern to the people living in the crude oil rich-areas (Ohanmu and Bako, 2017). Oil spills occurs as a result of failure in wellhead, leakage along the pipe lines during transportation, human sabotage and accidental discharge (Emuh, 2009). When crude oil is spilled on land, it affects the physicochemical properties of the soil, such as its temperature, structure, nutrient status and pH (Udeh *et al*., 2013).

Essien and John (2010) reported the frequent spillage on agricultural soils, and the consequent effect on all forms of life by rendering the soil (especially the biologically active surface layer) toxic and unproductive. This reduces the soil's fertility such that most of the essential nutrients are no longer available for crop and plant utilization (Abii and Nwosu, 2009).

Crude oil spillage also affects soil physical properties such as blocking their pore spaces thereby reducing soil aeration, infiltration of water into the soil and increased bulk density of the soil (Ohanmu *et al*., (2014). These soil properties are involved in soil-plant-water relationship which include texture, infiltration, hydraulic conductivity, moisture content, pH and density, which affect root and leaf development and plant growth and yield Chikere *et al*., (2006). Spilled crude-oil which is denser than water, reduces and restricts permeability in the soil. Organic hydrocarbons which fill the soil pores spaces expel water and air thus depriving the plant roots the much needed water and air (Warmate *et al*., 2011).

Okra (*Abelmoschus esculentus)* is an erect, semi-woody herbeaceous annual crop of the family Malvaceae. It is widely grown in the tropics and highly variable in growth from less than 1m to over 3m in height. The flowers are yellow and purple and fingerlike fruit which occurs at the leaf axis, the crop are grown on a wide variety of soils, a well-drained loamy soil is optimum for its growth. Okra leaves and fruits are eaten fresh and fried as pot-herb.

Soil is the most valuable component of the farming ecosystem and environmental sustainability largely depends on proper soil management (Ademipekun *et al*., 2009). Oil spills kills agricultural plant and inhibits the growth and performance of the entire vegetation cover (Lin and Mendelssohn 2012, and Okafor, 2023). Plants and vegetables crops have been described as the first victims of oil spill on land ecosystem (Odejimi *et al*., 2006). Oil spills readily penetrate the pore space of terrestrial vegetable crop (Sutton *et al*., 2013) with heavier friction which blocks the pores and this subsequently impedes photosynthesis and other physiological processes in plant.

This study therefore were to

i. examine the effects of crude oil pollution on physical and chemical properties of the soil.
ii. examine the effects of crude oil on seedling emergence and germination growth and yield of the Okra (A*belmoschus esculentus)*

MATERIALS AND METHOD

The research was carried out in Delta Steel Company (DSC) Technical High School, Farm in Udu, Delta State. Delta State Company Technical High School is located in Steel Town 1, Orhuwhorun, Delta State at Latitude 5° 80^{l} and 5° 20^{l} N and Longitude 5° 56^{l} and 5° 53^{l} E of the equator over an estimated area of about 138sq km. DSC Community is in Udu with its local government headquarters at Otor Udu, it has an estimated population of approximately 142, 480 people National Population Census (2006). Its position in the equator, falls within the humid environment characterized by heavy annual rainfall of 2768.8mm

(NIMET, 2021), the rainfall pattern is bimodal and usually begins in late March and ends in October. The heaviest peaks is usually noticed in the months of July-September with a tropical monsoon climate with mean temperature of 28.58°C.

Source of seed and Crude Oil

Seeds of V35 local variety of Okra (*Abelmoschus esculentus)* was sourced from National Horticultural Research Institute (NIHORT), lbadan while the crude oil was collected from the tank farm of the Warri Refinery and Petrochemical Company (WRPC) Limited. Ekpan, Warri.

Soil Sampling

The soil used for this study was collected from Delta Steel Company (DSC) Technical High School farm, which was air dried, screened to remove non degradable materials, 3kg each of the soil was measured into a perforated poly bags using a weighing balance, the perforated poly bags was laid out in a completely randomized design (CRD), in an open field cleared, the crude oil was measured at different rates of 0(control), 37.5ml, 75ml and 112.5ml. A measuring cylinder was used to measure the crude oil into each of the perforated polybags filled with top soil which was thoroughly mixed, then the contaminated soil was replicated three times which gives a total of 16 pots, following the method of Oluwanisola and Abdulrahaman (2018). The soils in the poly bags were watered to field capacity for two weeks prior to planting of the test crop (Okra). Hand weeding is done when necessary.

Data Collection

The following plant parameters were recorded such as days of emergence, plant heights and stem girths in each treatment were taken 7 days after planting (7DAP), subsequently it was taken 2 weeks after planting (2WAP). Five okra seeds of the V35 local variety was planted 4cm depth into the polluted and unpolluted soils in the perforated poly bags and was watered immediately and afterward to field capacity when necessary. Survival pattern was observed 3rd day after planting and thinning of the seedlings to 2 stands per pots was carried out 6days after planting to avoid overcrowding.

The stem girth was taken by means of a vernier caliper, while the height of the plant were taken with the aid of meter rule. The seedling emergence were visually counted and recorded while their percentages in each treatment was calculated, according to Osawaru *et al*., 2010 as: The germination percentage in each treatment was calculated

$$\textbf{\% E} = \frac{\text{number of seeds sprouted}}{\text{number of seeds sowed}} \times 100$$

The pods were visually counted, harvested with a knife and later weighed with an electronic weighing scale.

Soil Analysis

The soil samples collected were air dried, crushed, grind and pass through a 2mm meshed which were analyzed for both physical and chemical analysis, the analysis were done using the standard routine procedures.

The physical parameters determined are, particle size distribution, bulk density, moisture content, total porosity and saturated hydraulic conductivity (Ksat), some chemical parameters which were determined are pH, available phosphorus, total nitrogen and organic carbon and exchangeable bases (Ca, Mg, K and Na).

The particle size analysis were determined using the hydrometer method (Bouyoucous, 1951). Soil bulk density was determined using (core method). Total porosity (TP) was calculated from the parameters of bulk density using an assume value of 2.65g/cm^3 for particle density in the formula:

$$\% \text{ TP} = \frac{1-Pb}{Ps} \times 100$$

Where, PT = Total Porosity (%), Bd = Bulk density, Pd = Particle density.

The moisture content was determined using gravimetric methods. The percentage moisture content was calculated from the weight of water over the weight of the wet soil as;

%MC= weight of wet soil-weight of dry soil × 100
weight of wet soil

Saturated hydraulic conductivity was done with a constant head parameter. Soil pH was determined in water electrodes method. Soil organic carbon (OC) was determined by wet combustion method (Walkey and Black, 1934). Total nitrogen was determined by Kjeldahl digestion, distillation and titration method (Anderson and Ingram, 1993). Available phosphorus was determined using Olsen method (Olsen *et al*., 1982). Exchangeable bases were determined using Melich III extraction method (Adolf Mehlich, 1984).

Statistical Analysis

The data obtained was subjected to analysis of variance (ANOVA) and means showing significant differences were separated using Least Significant Difference at 5% level of probability.

RESULTS AND DISCUSSION

The results are presented in figures and tables which were used to record seed emergence, plant height, stem girth and yield growth in each treatment which were taken every 2 weeks for 63 days after planting (DAP).

Seed germination of okra

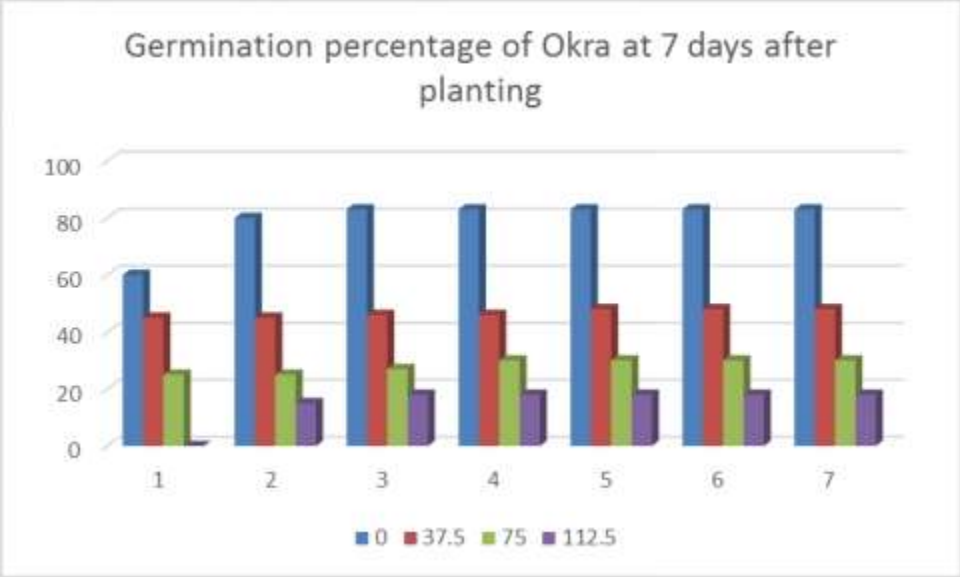


Fig. 1 showing germination percentage rate of Okra

The germination of okra as influenced by crude oil contamination are presented in Figure 1. Germination started at the third day after planting for (0ml) control, 37.5ml and 75ml while at the crude oil application of (112.5ml) germinating started on the fourth day. The plants percentage emergence increases was observed on daily basis. The control (0ml) had the highest percentage emergence of (83%), 37.5ml had 48% and 75ml had 30% and least was at crude oil application of 112.5ml per pot had the least percentage germination (18%). The higher the application of crude oil to the soil, the lower the germination rate, crude oil reduce soil aeration whereby preventing proper germination and emergence. This is in tandem with Agbogidi *et al*., (2012), and Singha and Pandey (2021) who reported low germination occur due to crude oil pollution of the soil.

Table 1: The effects of crude oil contamination on plant height of okra

	Weeks after planting				
Treatments	**1**	**2**	**3**	**4**	**5**
0.0	4.21a	8.90a	17.00b	32.02a	46.67a
37.5	3.38ab	8.00ab	11.05ab	15.44ab	22.15b
75	3.36ab	6.75bc	9.38b	11.80b	14.85c
112.5	2.52c	5.35c	6.73c	8.80c	13.35c

Means with similar alphabets on the same roll are not significantly different at 5% levels of probability using LSD.

The plant height monitored revealed that normal growth rate occurred at control and polluted soil with crude oil concentration on 37.5ml while at higher crude oil applications of 75ml and 112.5ml to the soils showed a retarded growth. Table 1 shows the results of the plant height of okra plants in the 4 treatment groups (0, 37.5, 75 and 112.5ml) respectively, these shows that there were significant difference ($p<0.05$) at the different levels, which implies that the responses of the plant were crude oil level dependent. The highest plant height was obtained in 0ml (control), followed by 37.5, 75 and 112.5ml polluted soils, with little or no variations. By 7days, the height of the control (0ml) emerged significantly higher ($p>0.05$) than the plants in the other treatment groups and the pattern was maintained till the end of the experiment. Among the treatment groups the height of pots of 112.5ml was found to be significantly lower ($p<0.05$) than any other treatment groups 37.5ml and 75ml. There was a significant difference between the plant grown in unpolluted soil and those grown in soil with varying concentrations of crude oil. The statistical analysis revealed that plant grown in unpolluted soil were significantly higher than those raised in the crude oil polluted soils. However, the performance of the plants in the soils polluted with crude oil is concentration dependent. The plant grown in soil with 37.5ml of crude oil performed better than those raised in soils contaminated with 75ml and 112.5ml of crude oil when compared statistically, this revealed that polluted soil with crude oil negatively affected the height of the okra. These observations agreed with the findings of Agbogidi *et al.*, (2007), Njoku *et al.*, (2012) and Uquetan *et al.*, (2017), who in their different studies reported that crude oil have adverse effects on the plant height and stunted growth as the level of the crude oil pollution increases.

Table 2: Mean values for the plant stem girth of okra

	Weeks after planting				
Treatments	**1**	**2**	**3**	**4**	**5**
0.0	0.69a	1.00a	1.50a	2.15a	2.17a
37.5	0.55b	0.77b	1.37b	1.91b	2.13ab
75	0.55b	0.75b	0.85c	0.94c	1.08bc
112.5	0.55b	0.75b	0.76c	0.93c	0.90c

Means with similar alphabets on the same roll are not significantly different at 5% levels of probability using LSD.

At first week after planting, the plant girth ranged from 0.55 to 0.69cm. The highest girth was at 0.0ml, while 0.55cm girth was observed at applications of 37.5 to 112.5mls. At third and fifth weeks after planting, the plant girth decreased with increase in crude oil contamination of the soil. The least girth at final observation (5WAP) was 0.90cm at applications of 112.5ml while the highest plant girth was 2.17cm at 0.0ml of crude oil application (Table 2). The highest girth with lower crude oil application could be that crude oil pollution affects the production of growth hormones which regulate stem elongation and thickness. Table 2 shows the results, that there was no significant difference ($p<0.05$) in polluted soil of 37.5, 75 and 112.5ml in week 1 and week 2 but there was a significant difference ($p>0.05$) in control, 37.5ml compared to polluted soils in 75 and 112.5ml for week 3, week 4 and week 5. The stem girth with control had the highest, this was followed by the least crude oil concentration. The 75ml and 112.5ml had the lowest stem girth. The least girth with higher crude oil application could be due to the

effects of crude oil in the soil.. This agreed with Emuh (2010), Ohanmu *et al*., (2017) and Okoh (2023) who reported that oil pollution reduced plant growth. Similarly, Ogbuchi *et al.,* (2011) reported that crude oil applications significantly reduced the stem girth of Arachis hypogea. This is in agreement with Agbogidi *et al*, 2009a, Njoku *et al*, 2012 reported that stem girth responded to the levels of crude oil.

Table 3: Effects of crude oil pollution on the yield of Okra (kg/plant)

Treatments (ml)	Number of fruits	Average weight of fruits (g)
0.0	16	90
37.5	8	50
75	4	20
112.5	0	0

The number of fruits and fruits weight ranged from 20-90g and 4-16 fruits for fruits weight and number of fruits respectively. The higher the crude oil application the lower the number of fruits and fruits weight. Table 3 shows the results of the okra yield in the 4 treatments (0, 37.5, 75 and 112.5ml) respectively, these shows that control (0ml) performed better than other treatment, while 37.5ml which is the least polluted soil did better than 75 and 112.5ml. In other words, crude oil polluted soil effects the performance and low fruit yield compared to plants in uncontaminated soil. This is in line with Emuh, (2019), who reported that crude oil significantly reduced the yield of maize at 9% v/w of crude oil pollution.

Table 4: Effects of Crude Oil on Soil Physical Properties

	Parameters						
Treatments (ml)	**Sand (%)**	**Silt (%)**	**Clay (%)**	**Bd (g/cm^3)**	**TP (%)**	**MC (%)**	**Ks (cm/s)**
0.0	48a	33ab	19a	2.27c	60a	1.67a	374.5a
37.5	44b	35a	21a	2.48b	57b	1.47b	141.1b
75	43b	37a	20a	2.50a	53b	1.30c	139.2c
112.5	41b	39a	20a	2.55a	49c	1.07d	135.1c

Means with similar alphabets on the same roll are not significantly different at 5% levels of probability using LSD. Bd–Bulk density, TP–Total Porosity, MC–Moisture Content, Ks–Hydraulic Conductivity.

The soil particles size analyzed showed that sand was dominant size fraction with values ranging from 41% - 48% (Table 4). The unpolluted soil was 48% while polluted soil reduced with increase in the level of crude oil pollution. The silt and clay fractions were similar at different levels of crude oil contamination in the soil. The results revealed a significant difference ($p<0.05$) between the control (0ml) and crude oil contaminated samples in all the particle size distributions. Percentage (sand) was significantly higher in the control treatment than contaminated soils. The textural class of the studied soil, is sandy loamy class. The result therefore, showed that contamination of the soil, did not change the textural class of the soil but leads to the aggregation of soil particles, altering the natural particle size distribution. Fine particles may clumps together due to the nature of crude oil, reducing the proportion of smaller pores in the soil. This finding is similar to the report of Okonokhua *et al*. (2007) and Abosede (2013), who reported that crude oil contamination of soil, does not have effects on the soil texture but changes the natural particle size distribution.

The bulk density of the soil, increases from $2.27g/cm^3$ in unpolluted soils to $2.55g/cm^3$ in the soils contaminated with crude oil. The significant increase ($p<0.05$) with increased in crude oil applications contaminated soil ($2.48gcm^3$ at 37.5ml, $2.50gcm^3$ at 75ml and $2.25gcm^3$ at 112.5ml) over control ($2.27gcm^3$) samples, is an indication that crude oil contamination, increases the bulk density of soil. A higher bulk density reduces soil porosity, making it harder for roots to penetrate and limiting water and air movement within the soil. This observation was affirmed by the findings of Mba *et al*., (2010), Ohanmu *et al*., (2014) and Nwite and Alu (2015) and Nwite *et al*., (2020). This agrees with the work of Iren and

Ediene (2017) who observed that the bulk density of the soil, increases with an increase in crude oil contamination and also reduces the soil porosity.

The effects of soil moisture content as influenced by crude oil contaminated soil are presented in Table 4. The mean values obtained, showed there was significant difference ($p<0.05$) in all levels of pollution when compared to control (1.67%).The percentage moisture content decreased with an increase in crude oil pollution. The lowest mean values were obtained in the highest applications of crude oil to soil of 112.5ml (1.07%). Crude oil repels water, leading to a decrease in the soil's moisture retention capacity and the reduction in moisture content negatively impacts plant growth and microbial activities that depend on water availability. Thus, Essien, *et al.,* (2010), who reported that the higher the level of crude oil contamination in soils, the lower the levels of soil moisture contents of the soil.

The soil hydraulic conductivity increased from 135.1cm/s in contaminated soils to 374.5cm/s in control samples. The decrease in hydraulic conductivity with increase in crude oil contaminated soil, over the control soil as a result of the increase levels of crude oil contamination in the soil in other words, the ability of soil to transmit water, is significantly reduced in crude oil-contaminated soils whereby oil blocks soil pores, decreasing permeability and restricting the movement of water through the soil. This observation is in line with the report of Agbogidi and Enujike (2012) and Ogboghodo *et al*. (2005), who in their studies, noted that soil contaminated with spent oil reduced the soil hydraulic conductivity in the soil.

Table 5: Effects of Crude Oil on Soil Chemical Properties

					Exchangeable Bases			
Treatments (mls)	**pH**	**OC (g/kg)**	**TN (g/kg)**	**AP (ppm)**	**Ca (cmol/kg)**	**Mg (cmol/kg)**	**K (cmol/kg)**	**Na (cmol/kg)**
0.0	5.97a	3.68c	1.12c	3.59a	2.81a	1.87a	1.56a	1.28a
37.5	5.80b	3.71b	1.76b	1.86b	2.76b	1.82a	1.53a	1.18b
75	5.78b	3.93a	1.86a	1.64c	2.53c	1.79b	1.50a	1.12c
112.5	5.68b	3.96a	1.88a	1.56d	2.34d	1.79b	1.48b	1.12c

Means with similar alphabets on the same roll are not significantly different at 5% levels of probability using LSD. OC–Organic Carbon, TN-Total Nitrogen, AP–Available Phosphorus, Ca-Calcuim, Mg-Magnesium, K-Potassium, Na-Sodium.

The values obtained for soil pH in control and polluted soils are shown in Table 5. There was a significant difference ($p<0.05$) between contaminated soil and control but no significant difference ($p>0.05$) among the polluted soils. The pH of the soil is moderately acidic, values of the polluted soil samples, varies from 5.68 to 5.80 (Table 5) in 37.5, 75 and 112.5ml respectively. The differences in the pH can be attributed to the increase of the crude oil concentration, this implies that pH can reduce the availability of essential nutrients, negatively affecting plant growth and microbial activities. This is in agreement with Vwioko *et al.,* (2008) who reported that increase in crude oil, reduces soil acidity in an acidic soil which increases the soil pH.

Results from the chemical parameters indicated that percentage organic carbon is higher with corresponding crude oil pollution with 3.96% than the unpolluted soil with 3.68%, there was no significant difference ($p<0.05$) between contaminated soil, but significant difference between contaminated soil and control. However, soil organic carbon concentration increased progressively with an increase in crude oil pollution which implies that crude oil is rich in hydrocarbons, which significantly increase the organic carbon content of the soil upon contamination. Amadi *et al*., (1993) reported a value of 3.69% from crude oil-polluted soil as percentage enhanced organic carbon content of the soil.

Results obtained for Total nitrogen content both in control and crude oil polluted samples are shown in Table 5. The values obtained at different percentage of soil pollution with crude oil and polluted soils, show that there was a significant difference ($p<0.05$) in total nitrogen concentration as the percentage crude oil in the soil increased which lead to nitrogen immobilization, where microbes consume available nitrogen to break down hydrocarbons, making it unavailable to plants. This is in line with the findings of

Ayolagha *et al*. (2006) and Oyedeji *et al*.,(2012), who reported that, the increase in Total Nitrogen in crude oil contaminated soil over unpolluted soil was attributed to mineralization by microorganisms during degradation of crude oil in the soil.

The results for Available phosphorus in the soil is presented in Table 5. There was a significant difference ($p>0.05$) between the values obtained in polluted soil, when compared to the control. Between the three levels of contaminated soil the available phosphorus decreased with increase in the crude oil levels. The application of 112.5ml had the least, this could be phosphorus availability is significantly affected by crude oil contamination, This agreed with Ogboghodo *et al*., (2004) who reported that there is a decrease in available phosphorus with increase in the levels of crude oil pollution in the soil.

The exchangeable bases results obtained are shown in Table 5. The Ca ranged from 2.34 to 2.81 while K ranges from 1.48 to 1.56 (Table 5). Crude oil contamination can reduce the availability of calcium and magnesium by altering soil structure and increasing soil compaction. This limits their mobility and exchangeability, leading to nutrient deficiencies that affect plant growth and development. The decrease in all the exchangeable bases decreased with an increase in crude oil pollution, which indicates an interference in mineral demobilization after oil treatments. This is in line with Marinescu (2011) who reported that increase in polluted soils led to decrease in exchangeable bases.

CONCLUSION AND RECOMMENDATIONS

Crude oil contamination has a detrimental effects on the germination and growth of okra plants, which causes delayed in seed germination and reduction in plant height, stem girth and overall the fruit yield. Although crude oil contamination did not alter the soil's textural class, which is sandy loam, the results equally revealed that physical parameters of the soil that are significantly affected are saturated hydraulic conductivity, moisture content, total porosity and bulk density of the soil, all these properties are been controlled by the pore spaces that are present in the soil. Crude oil contamination also have a profound effects on chemical properties, the soil pH, available phosphorus and exchangeable bases decreases with increase in crude oil pollution whereas organic carbon and total nitrogen were increased upon crude oil pollution. With these findings, it is expedient to conduct comprehensive soil testing before cultivating okra or any other crops in areas with potential crude oil contamination to ensure soil safety is important for protecting human health and maintaining agricultural productivity. The study strongly recommends minimizing crude oil contamination and were possible total prevention of contamination of agricultural soils with crude oil.

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