Remediation of Soil Contaminated with Petroleum Products Using Poultry Manure for the Growth of Okra (*Abelmoschus Esculentus)*

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Abstract
A study on remediation of soil contaminated with petroleum products (kerosene, fuel and diesel) for the growth of okra *(Abelmoschus esculentus*) was carried out at Department of Biology, research farm site Federal University of Technology, Owerri. The study was conducted on soil sample collected from the Federal University of Technology, Owerri. The top soil (0-10cm) was collected from the open field at the Biology research farm site and sieved using a 5mm mesh to remove gravel and debris. The set of soil samples were contaminated with petroleum products to achieve 0 and 5ml pollution each of kerosene, petrol and diesel, of which the concentration were 0% concentration, 50% concentration each of kerosene, petrol and diesel were amended with poultry manure. The experimental design used was Completely Randomized Design (CRD) in four replications. Samples were analyzed at eight weeks after planting using Analysis of Variance (ANOVA) and means were separated by least significant difference (LSD) at 95% confidence interval. The plant growth parameters were affected adversely by the contaminated soil. The higher the level of pollution, the more the effect. The amendments (poultry manure) were able to remedy the effect of the pollutant. The study showed that soils contaminated with petroleum products had adverse effect on plants growth, in a concentration dependant form but this was remedied by addition of organic nutrient supplements such as poultry waste.

Keywords: Petroleum products, Pollution, Remediation, Okra

Introduction

Background of the Study

Nigeria is one of the petroleum producing countries, but the industry has created both economic developments alongside environmental hazards. Petroleum products are some of the most widely used chemicals which because of their wide usage, can easily spill, leak or be discharged to the environment. The leakage, discharge and spillage of petroleum products can lead to pollution of terrestrial and aquatic environments. Soil contaminated by petroleum products has been shown to be one of the world's most common environmental problems (Agbogidi et. *al.,* 2007). The presence of petroleum products in the environment poses danger to the growth of plants and the wellbeing of animals' resident or dependent on the environment. Several researchers have shown that the individual petroleum products have effects on the growth and performance of plants. Microorganisms and plants have complementary role in rhizoremediation of oil-polluted soil. The plant *rhizosphere* is recognized as a niche rich in growth substrates in comparison with the surrounding bulk soil. Rhizospheres are dynamic microenvironments in which microbial communities have access to an elevated supply of carbon, oxygen and energy rich materials from plant roots (Kuiper *et. al.,* 2004). Rhizospheres are also stable physically, avoiding the potentially adverse effects of naturally occurring disturbances on microbial community composition or activities (Kuiper *et. al.,* 2004). The success of rhizoremediation of hydrocarbon contaminated soil is dependent on the plant capacity to enhance the microbial activity in the plant rhizosphere, which is the main factor for the remediation of contaminated soil is the rhizosphere microflora of the plant adapted to the contaminant (Muratova *et. al.,* 2003). Microorganisms on the rhizosphere exert big effect on plants; they lead to a continuous breakdown of organic and mineral compounds, which become available to plants. Moreover, they produce organic and non-organic acids, influence the dissolution of mineral salts and protect the plants against the phytopathogens.

Contamination of soil by oil spills is a wide spread environmental problem that often requires cleaning up of the contaminated sites (Bundy *et. al.,* 2002). This is because petroleum hydrocarbons in soils adversely affect the germination and growth of plants (Samina *et. al.,* 2001) by creating conditions which make essential nutrients like nitrogen and oxygen unavailable. According to Adam and Duncan, (2002), this effect could be because the oil acts as a physical barrier preventing or reducing access of the seeds to water and oxygen. The economic growth that Nigeria has enjoyed as a result of oil revenue had drawbacks through exposure of the population in oil producing areas to environmental contamination (Anoliefo et. *al.,* 2006). The possibility of growing plants on soils contaminated by fuel or oil spills is one of the goals of bioremediation.

Soil remediation is defined by Allen, (1988) as the return of soil to a condition of ecological stability together with the establishment of plant communities it supports or supported prior to disturbance. Among hydrocarbon pollutants, diesel oil is a complex mixture of alkane and aromatic compounds that are frequently reported as soil contaminants leaking from storage tanks and pipelines or released in accidental spills. Contamination of soil results in damage to crop growth; depending on the degree of contamination, the soil may remain unsuitable for plant growth for months or several years. The effect of contamination of soil with petroleum products on plants ranges from chlorosis, bleaching, spotting of leaves, necrosis, malformations of epidermal cells and mesophyll layers, yield reduction and impaired fecundity (Quinone-Aquilar *et. al.,* 2003). Achuba (2006) reported that toxic hydrocarbon molecules could inhibit the activities of amylase and starch phosphorylase and thereby affect the assimilation of starch. Henner, *et. al.,* (1999) reported that petroleum hydrocarbons consisting of small molecules and those that are water soluble are more phytotoxic to seed germination. Diesel fuel is not a systemic killer; it kills plants cells on contact. Spent fuel was described by Wang, *et. al.,* (2000) as a mixture of different chemicals including lubrication additives and heavy metals that come from engine parts as they wear away. Spent fuel is a toxic environmental contaminant not usually or naturally found in the environment. Due to the different composition of diesel fuel, it affects the environment in different forms. Thus, the organic carbon and mineral component in soil are affected at different rates. The implication of this is that the growth and development of organisms depending on such soils are affected at different rates.

Abelmoschus esculentus (Okra) is one of the very easily affordable vegetables in the area where the present study was conducted; Owerri, Imo State, Nigeria. It is usually sown around houses and nearby farms, including those located very near to auto mechanic workshops and petro station. This research work was carried out because of the harmful effect of hydrocarbon in the form of waste petroleum products that has destroyed farmlands across country. The question that usually arises when seeds are sown in oil-polluted soil is whether or not the seeds would grow considering the phytotoxic effects of oil on germination and seedling development

The result obtained from this study will provide baseline information on the remediation of soil contaminated with petroleum products for the growth of *Abelmoschus esculentus* (Okra). The awareness can provide the effective remedies and the suggestions toward effective control of petroleum spillage and the associated damages they cause in the environment

It is hoped that this study would provide a ready guide to policy makers and other stakeholders to make informed decisions in relation to implementing action plans geared towards the sustainable development of the region. It would also help in updating existing policies and interventions aimed at empowering the local communities of the region economically. The study would recommend strategies that could be adopted by the decision-makers and stakeholders in mitigating pollution of water bodies and agricultural lands, which contribute immensely to the economic well-being of the local people.

Material And Methods

Study Location

The research was conducted on soil sample collected from the Federal University of Technology, Owerri. The University is located on a GPS between Latitude 40N and 50N and Longitude 60E and 70E. The experimental site was an open field and test crops were potted at the Biology research farm site. The mean precipitation (rainfall) for the area is about 2500 mm/year, while the minimum and maximum temperatures were 25^{o}C and 35^{o}C.

Soil Sample Collection

The top soil (0-10cm) was collected from the open field at the Biology research farm site and sieved using a 5mm mesh to remove gravel and debris for the study.

Concentrations of petroleum products contamination

The soil samples collected were contaminated with 0 and 5ml each, of kerosene, petrol and diesel to produce 0% concentration and 50% concentrations of kerosene, petrol and diesel respectively.

Remediation of petroleum products polluted soils

The remediation of polluted soils was done by using 10kg of poultry manure. This was added to the replicates of the soils polluted with kerosene, petrol and diesel for two (2) weeks before planting.

Planting of Test Crop
After remediating the soil, okra seeds were sown two weeks after application of poultry manure.

Experimental design and Treatment
The experimental design used was complete randomized design with

Polluted phase
T0 Control (No Pollution)
T1 50% Concentration of Kerosene
T2 50% Concentration of Petrol
T3 50% Concentration of Diesel

Remediation Phase
T4 50% Concentration of Kerosene + 10kg of Poultry Manure
T5 50% Concentration of Petrol + 10kg of Poultry Manure
T6 50% Concentration of Diesel +10kg of Poultry Manure

Experimental Parameters
Growth parameters, including numbers of days taken for seedling emergence, plant height, leaf number, number of branches as well as yield parameters.

Seedling emergence
The seedling emergence was counted and recorded

Number of Leaves
The leaves number count was done by counting the leaves, taking into consideration all leaves for each plant in the experimental pot.

Number of branches
The branches number count was done by counting the branches and recorded.

Plant Height
Plant height was determined by measuring the shoots of the plant in the plant pots from the soil level to the terminal bud using a metre rule. Average mean plant height was determined.

Number of pods
The number of pods was done by counting the number of pods, taking into consideration all pods for each plant in the experimental pot.

Soil analysis:
Soil analysis was carried out on the uncontaminated, contaminated (after stabilization period), and remediated soil samples. The soil bulk density, porosity, specific gravity, pH and Total hydrocarbon content (THC) in the soil sample were determined using the standard method recommended by Al-Baldaw *et. al.,* (2015).
Particle size procedures: The percentage sand, silt and clay were determined using the bouyoucos hydrometer method according to Nelson and Sommer, (1991). The sizes of the solid in the suspension were determined.
Soil pH determination: This was determined in a suspension of soil water at ratio of 1:2 soil to water and measured using a glass electrode pH meter as was described by Nelson and Sommer, (1982)
Available phosphorus determination: This was determined using the Bray method of Grossman and Ranches, (2002)
Exchangeable Base: These were determined from ammonium acetate (NH4OAC) leachate of soil. Exchangeable calcium and magnesium were determined by the EDTA (Ethylene Diamine Tetra-Acetic Acid) Versanate titration method. Exchangeable potassium was determined by the flame photometer method
Total Nitrogen determination: This was determined using the micro kjeldahl digestion method apparatus (Nelson and Sommers, 1991)
Organic carbon and Organic matter determination: The organic carbon content of the soil sample was determined by Walkey-Black method and organic matter (Grossman and Ranches, 2002). The organic matter was determined by multiplying organic carbon with Van Bemmelen factor of 1.724

Heavy metal determination

The heavy metals (copper, Iron and Lead) were determined using an atomic absorption spectrophotometer, in accordance with standard methods (Akpokodje *et. al.,* 2018). The samples were mixed gently and homogenized, sieved through 2mm mesh-sieve. The samples were first dried, and then placed in electric oven at a temperature of 400c approximately for 30 minutes. The resulting fine powder was kept at a room temperature for digestion. Flame atomic absorption spectrophotometer apparatus (Buck scientific 210 spectrophotometer) was used to measure the concentration of heavy metals in the specimens, after making the calibration graphs, three samples were taken for each element and the average concentration was recorded.

Determination of bacteria and fungi

After the serial dilution, agar plating on the vials, following warcups soil plate and waksman direct inoculation methods, 0.5g of the soil sample was added to the Erlenmeyer flask containing 50 ml of agar and shake well for one minute. 0.5 ml was placed in a vial containing 4.5 ml of 0.1% agar. 1ml was pipette into each of the petri dishes containing potato Dextrose Agar (PDA) and was spread over the entire surface using glass stirring rod. The petri dishes were sealed with the paraffin and were incubated at room temperature and observed after 24 and 48 hours. The number of colonies per petri dish was recorded and counted. Identification of isolates is an essential procedure employed to determine whether or not a microbial isolate belongs to any of the already established taxonomic groups and naming them. In this study, standard techniques were used to characterize and identify microbial isolates obtained from the cultures. The bacterial isolates were identified according to Fawole and Oso (2004). Fungal isolates were identified according to the methods of Compbell and Stewart (1980) and Baird et al. (2002) using the physiological and morphological features of isolates. Morphological characteristics (colour, shape of colonies, surface elevation, consistency, margin and 98 Gram stain microscopy) were used for bacteria, while identification of fungi was performed using morphological characteristics and staining.

Statistical Analysis

Data obtained were subjected to analysis of variance (ANOVA) and means we're separated using significant difference (LSD) at 0.05 percent level.

Results And Discussion

Table 1: Physicochemical properties of polluted and non-polluted soil with petroleum products before and after soil remediation

Treatment	pH	OC	OM	TN	AP	Ca	K	Mg	Textural Class (TC)	Sand (%)	Silt (%)	Clay (%)
Before Soil Remediation												
0% Conc. (Control)	5.39	0.76	0.68	0.040	26.59	0.42	0.13	0.22	SL	87.15	5.22	5.61
DPK (50% Conc.)*	4.22	2.68	0.27	0.021	16.16	0.37	0.12	0.22	SL	82.96	5.10	5.02
PMS (50% Conc.)	4.12	3.25	0.26	0.022	16.79	0.38	0.11	0.22	SL	82.62	5.04	5.02
AGO (50% Conc.)	4.84	3.43	0.25	0.020	13.77	0.36	0.12	0.22	SL	81.81	5.03	5.01
After Soil Remediation												
0% Conc. (Control)	5.39	0.76	0.68	0.040	26.59	0.42	0.13	0.22	SL	87.15	5.24	5.63
DPK (50% Conc.)	5.37	3.68	0.82	0.024	19.16	0.41	0.13	0.22	SL	78.22	5.09	4.74
PMS (50% Conc.)	5.35	3.45	0.80	0.025	16.80	0.42	0.12	0.22	SL	72.96	5.10	4.39
AGO (50% Conc.)	5.41	3.53	0.83	0.024	14.82	0.40	0.11	0.22	SL	78.45	5.27	4.42

OC= Organic Carbon, OM= Organic matter, TN= Total Nitrogen, AP= Available Phosphorus, Ca= Calcium, TC= Textural Class, K= Potassium, Mg= Magnesium, SL= Sandy Loam, DPK= Dual purpose kerosene, PMS= Premium motor spirit, AGO= Automotive gas oil

Results on physicochemical properties of polluted and non-polluted soil as presented in table 1 suggested that the effect of crude oil and spent lubricating oil on soil texture resulted in a slight increase in the silt content as compared to the control due to compaction of soil particles. Findings show a gradual increase in soil pH with increased treatment concentrations. The increase is attributed to the accumulation of exchangeable bases in the oil polluted soils which further affects the ionic stability of the soil and conversely nutrient availability and uptake by the plants. Organic carbon increased markedly with an increase in treatment concentration for all the crops. The observed values of organic carbon were above the 2.0% critical level required for normal plant growth. This can be attributed to slow decomposition by facultative and obligate anaerobes. This could also be because microorganisms have adapted to soil conditions and were now able to utilize the carbon content of the soil for their metabolism. Also, K+ and Mg+ decreased with increased treatment concentrations for all the crops. This is in tandem with Ekundayo *et al.,* (2009). The plausible reasons for these decreasing trend might be due to the conversion of $H_2PO_4^-$ (most available form of phosphorus) to HPO_4^{2-} (less available form for plants uptake) and then to PO_4^{3-} as the soil pH increases (Asuquo *et al.,* 2001).

Heavy metal contents in polluted and unpolluted soils with some petroleum product

Table 2: Heavy metal contents in polluted and unpolluted soils with some petroleum products

Sample identity	**PARAMETERS (mg/kg)**	**Control (unpolluted)**	**Kerosene (DPK)**	**Petrol (PMS)**	**Diesel (AGO)**
S1	Pb	ND	23.45	25.47	28.67
	Ni	ND	87.44	86.65	91.56
	Mn	ND	89.43	96.71	97.57
	Zn	ND	112.23	114.71	112.07
	Fe	66.78	110.31	112.38	117.56
S2	Pb	ND	24.11	26.04	27.98
	Ni	ND	86.67	88.48	92.94
	Mn	ND	107.41	118.72	120.08
	Zn	ND	116.83	117.17	120.25
	Fe	68.34	102.38	111.73	113.3
S3	Pb	ND	22.56	24.97	24.99
	Ni	ND	89.81	95.33	92.53
	Mn	ND	86.00	88.63	89.78
	Zn	ND	117.42	119.8	121.4
	Fe	68.99	116.34	116.55	117.41

Pb (Lead), Mn (Manganese), Zn (Zinc), Fe (Iron)
ND= Not Detected S1-3 = Soil samples in triplicates DPK= Dual purpose kerosene, PMS= Premium motor spirit, AGO= Automotive gas oil

Levels of extractable heavy metals (Mn, Cu, Ph, Ni, and Zn) concentration in soil samples based on Wielding and Dress (1983) rating after experiment portrays that Mn, Fe, Zn, Cu and Ni were highly variable. The content of all the heavy metals was lowest in the unpolluted soil. Results showed that oil pollution increases total manganese (Mn) and lead (Pb) in the soil. Though Pb did not exceed the permissible range for agricultural soils which is 10-30mg/kg^{-1}, such can't be said of Mn which exceeded the permissible range for soils (20-90mg/kg^{-1}). Iron (Fe) sufficiently increased than any other heavy metal in the soil. Plausible reasons that all soils contain significant concentration of iron. Findings as reported by Agbogidi et. *al., (*2007), identify crude oil spillage as an important pathway by which heavy metal contamination of soils is brought about apart from municipal wastes, industrial effluents and mining. This also creates a pathway for heavy metals into the food chain through which they are passed to animals and man. When once the soil is polluted, heavy metals are locked up in the soil; they undergo oxidation which results in the distribution of their ions within the soil system and hence becoming potentially bio-available as they are absorbed by plants and are further recycled.

Identification of Microbial Isolates

Table 3: Microbial population before and after remediation with poultry manure

Treatment	Bacteria ($\times 10^6$ cfu/g)	Fungi ($\times 10^6$ cfu/g)
Before Soil Remediation		
Unpolluted	2.92	0.27
DPK	1.90	0.65
PMS	1.73	0.64
AGO	1.37	0.66
After Soil Remediation		
Unpolluted	2.93	0.29
DPK	2.73	0.36
PMS	2.68	0.33
AGO	2.51	0.31

From the study, there were more bacteria counts after soil remediation (poultry manure) but fungi counts in the site soil decreased with increased oil concentration significantly after soil remediation. The results indicate that oil contamination/spillage alters the population of indigenous soil microbes, particularly at high concentrations as shown in table 3.

Growth Performance of *A. esculentus* grown on petroleum products polluted soils with poultry manure remediation at two weeks after planting (WAP)

Table 4a: Mean growth parameters of *A. esculentus* in crude oil-contaminated soil at 2 WAP*

Treatment	Seed Germination (%)	Plant Height (cm)	Plant Girth (cm)	No. of Leaves	No. of Branches
Polluted Phase					
T_0 (Control)	51.0	$6.4^a \pm 1.7$	$2.2^b \pm 0.4$	$3.0^c \pm 0.3$	$2.1^b \pm 0.2$
T_1 (50% Kerosene)	32.6	$3.8^b \pm 1.0$	$1.2^c \pm 0.1$	$2.4^d \pm 0.4$	$1.4^c \pm 0.1$
T_2 (50% Petrol)	31.3	$4.0^b \pm 1.0$	$1.3^c \pm 0.1$	$2.3^d \pm 0.2$	$1.2^c \pm 0.1$
T_3 (50% Diesel)	36.7	$3.6^b \pm 1.0$	$1.3^c \pm 0.1$	$2.2^d \pm 0.2$	$1.4^c \pm 0.1$
Remediation Phase (15 kg Poultry Manure)					
T_4 (50% Kerosene)	69.8	$7.6^a \pm 1.7$	$3.4^a \pm 0.6$	$4.4^{ab} \pm 0.8$	$3.3^a \pm 0.5$
T_5 (50% Petrol)	72.5	$8.1^a \pm 1.8$	$3.7^a \pm 0.7$	$4.7^a \pm 0.9$	$3.8^a \pm 0.6$
T_6 (50% Diesel)	68.4	$7.7^a \pm 1.7$	$3.5^a \pm 0.6$	$3.8^b \pm 0.7$	$3.5^a \pm 0.6$

Mean along the column having different superscript of letters differ significantly at p=0.05 level according to Dungan Multiple range test (DMRT)

The mean growth performance of *A. esculentus* on petroleum products polluted soils affected the seed germination, plant height, plant girth, number of leaves and number of branches at two weeks after planting (WAP) on test crop while the remediated soils gave the best performance with 15kg poultry manure at p=0.05 level (Table 4)

Growth Performance of *A. esculentus* grown on petroleum products polluted soils with poultry manure remediation at four weeks after planting

Table 4b: Mean growth parameters of *A. esculentus* remediated with poultry manurein crude oil-contaminated soil at 4 WAP

Treatment	Plant Height (cm)	Plant Girth (cm)	No. of Leaves	No. of Branches
Polluted Phase				
T_0 (Control)	$7.4^b \pm 1.9$	$3.4^b \pm 0.4$	$4.3^b \pm 0.8$	$3.7^b \pm 0.7$
T_1 (50% Kerosene)	$4.2^c \pm 1.2$	$2.1^c \pm 0.1$	$3.4^c \pm 0.5$	$2.5^c \pm 0.4$
T_2 (50% Petrol)	$4.1^c \pm 1.4$	$2.2^c \pm 0.4$	$3.5^c \pm 0.6$	$2.6^c \pm 0.5$
T_3 (50% Diesel)	$3.9^c \pm 1.1$	$2.0^c \pm 0.2$	$3.0^c \pm 0.3$	$2.7^c \pm 0.6$
Remediation Phase (15 kg Poultry Manure)				
T_4 (50% Kerosene)	$8.7^a \pm 1.8$	$4.3^a \pm 0.8$	$5.6^a \pm 1.0$	$4.3^a \pm 0.9$
T_5 (50% Petrol)	$9.2^a \pm 1.9$	$4.4^a \pm 0.9$	$5.4^a \pm 0.9$	$4.7^a \pm 0.8$
T_6 (50% Diesel)	$8.5^a \pm 1.7$	$4.3^a \pm 0.8$	$5.5^a \pm 1.0$	$4.2^a \pm 0.8$

Growth Parameters

Mean along the column having different superscript of letters differ significantly at p=0.05 level according to Dungan Multiple range test (DMRT)

Table 4b shows the results on growth parameters of *A. esculentus* contaminated with petroleum products of which the growth parameters of *A. esculentus* were reduced significantly. The growth parameters of remediated soils were significantly high with application of 15kg of poultry manure. The plant height, plant girth, number of leaves and number of branches at four weeks after planting (WAP) performed excellently well than the polluted phase as shown in table 4b.

Growth Performance of *A. esculentus* grown on petroleum products polluted soils with poultry manure remediation at six weeks after planting (WAP)

Table 4c: Mean growth parameters of *A. esculentus* remediated with poultry manure in crude oil-contaminated soil at 6 WAP

Treatment	Plant Height (cm)	Plant Girth (cm)	No. of Leaves	No. of Branches
Polluted Phase				
T_0 (Control)	$7.8^b \pm 2.1$	$3.6^b \pm 0.8$	$4.6^b \pm 0.6$	$3.9^b \pm 0.9$
T_1 (50% Kerosene)	$4.3^c \pm 1.5$	$2.3^c \pm 0.5$	$3.5^c \pm 0.5$	$2.8^c \pm 0.8$
T_2 (50% Petrol)	$4.5^c \pm 1.6$	$2.4^c \pm 0.4$	$3.7^c \pm 0.8$	$2.8^c \pm 0.8$
T_3 (50% Diesel)	$4.2^c \pm 1.5$	$2.2^c \pm 0.3$	$3.2^c \pm 0.4$	$3.0^c \pm 0.8$
Remediation Phase (15 kg Poultry Manure)				
T_4 (50% Kerosene)	$9.4^a \pm 2.3$	$5.1^a \pm 1.2$	$6.3^a \pm 1.4$	$5.6^a \pm 1.4$
T_5 (50% Petrol)	$9.5^a \pm 2.4$	$5.2^a \pm 1.3$	$6.2^a \pm 1.2$	$5.4^a \pm 1.2$
T_6 (50% Diesel)	$9.6^a \pm 2.5$	$5.4^a \pm 1.4$	$6.1^a \pm 1.0$	$5.3^a \pm 1.4$

Growth Parameters

Mean along the column having different superscript of letters differ significantly at p=0.05 level according to Dungan Multiple range test (DMRT)

The results on growth performance of *A. esculentus* at six weeks after planting were indicated on table 4c of which the remediated soil on growth performance of *A. esculentus* did the best. The polluted phase test crop was adversely affected by petroleum products contamination of which the growth performance was affected as shown.

Growth Performance of *A. esculentus* grown on petroleum products polluted soils with poultry manure remediation at eight weeks after planting (WAP)

Table 4d: Mean growth parameters of *A. esculentus* remediated with poultry manure in crude oil-contaminated soil at 8 WAP

Treatment	**Plant Height (cm)**	**Plant Girth (cm)**	**No. of Leaves**	**No. of Branches**
Polluted Phase				
T_0 (Control)	$10.3^b \pm 2.1$	$4.4^b \pm 0.8$	$6.8^b \pm 1.4$	$5.5^b \pm 1.0$
T_1 (50% Kerosene)	$5.2^c \pm 1.5$	$3.3^c \pm 0.4$	$4.7^c \pm 0.9$	$3.7^c \pm 0.8$
T_2 (50% Petrol)	$5.3^c \pm 1.4$	$3.0^c \pm 0.4$	$4.5^c \pm 0.8$	$4.0^c \pm 0.7$
T_3 (50% Diesel)	$5.1^c \pm 1.3$	$3.3^c \pm 0.4$	$4.7^c \pm 0.9$	$4.0^c \pm 0.8$
Remediation Phase (15 kg Poultry Manure)				
T_4 (50% Kerosene)	$15.6^a \pm 2.5$	$6.2^a \pm 1.2$	$8.1^a \pm 2.6$	$7.6^a \pm 2.4$
T_5 (50% Petrol)	$16.0^a \pm 2.6$	$6.3^a \pm 1.3$	$8.4^a \pm 2.8$	$8.0^a \pm 2.5$
T_6 (50% Diesel)	$16.1^a \pm 2.6$	$5.9^a \pm 1.1$	$8.2^a \pm 2.7$	$7.9^a \pm 2.7$

Mean along the column having different superscript of letters differ significantly at p=0.05 level according to Dungan Multiple range test (DMRT)

At eight weeks after planting, the remediated soil gave the best performance on plant height with T_6 (50% conc. of diesel + 15kg of poultry manure) 16.1cm followed by T_5 (50% conc. of petrol + 15kg of poultry manure) 16.0cm, T_4 (50% conc. of kerosene + 15kg of poultry manure) 15.6cm, T_0 (control) 10.3cm and the least was the polluted phase at p=0.05 level. The same trend was observed on plant girth, number of leaves and number of branches respectively as shown.

Discussion

Soil is the most important component of the farming ecosystem, and environmental sustainability largely depends on proper soil maintenance and management. Sustainable use of soil on which agriculture depends is absolutely necessary for an optimal agricultural productivity. Soil pollution by crude oil has posed a great menace to agricultural productivity and thus created poverty and hunger among the populace. It was observed from this experiment that petroleum products in agricultural soil affected agricultural productivity. Petroleum products pollution in agricultural soil in whatever form is toxic to the plant and soil micro environments. It has been observed by several researchers Adenipekun *et. al.,* (2009), Anoliefo & Vwioko (2005) that crude oil affects agricultural soil and this in turns affect the physiological, ecological and anatomical development of plants grown on such soils and this is in consonance with the outcome of the present studies.

Germination of *Abelmoschus esculentus* (Okra) plant was delayed in petroleum products polluted soil, though this effect was concentration dependent. This is in agreement with the result obtained by Adenipekun *et. al.,* (2009) that oil in soil above 2% concentration affects the growth of okra adversely and severely. Petroleum products spill into agricultural soil therefore affects the germination, plant physiology and ecology and ultimately the growth and anatomical development of okra planted in the field. The presence of high contents of heavy metal in soils has been shown to adversely affect crop growth due to the interference of these metals with physiological and biochemical activities, inhibition of photosynthesis, respiration, activities of organelles and plant survival. The decrease in heights and girths of plant in petroleum products-polluted soil may be due to the non-availability of adequate water, which possibly affected the nutrient uptake and mobility. This study thus, shows that artificial introduction of petroleum products on agricultural soil has considerable adverse and severe effects on the germination, plant physiology and ecology as well as agronomic growth and development of some vegetable crops particularly *Abelmoschus esculentus* (Okra) in the Owerri.

Conclusion

This study revealed that the introduction of crude oil into agricultural soil adversely and severely inhibits agronomic growth and development of *Abelmoschus esculentus* and reduces its height and girth. This would probably affect the yields from the plant. Oil pollution had significant influence on soil properties and crop growth which render such soils temporarily unsuitable for cropping for some time before being degraded. Oil pollution increases soil organic carbon, total nitrogen and total hydrocarbon. Available phosphorus, exchangeable K^+, Na^+ and Ca^{2+} decreases with increase in treatment concentration. Heavy metals in the soil were highly variable as Fe, Mn, Pb, Ni contents were increased as treatment concentration increases.

Declarations

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Authors contributions

The work was conducted in collaboration among all authors. Authors NSN and NMO designed the study, wrote the first draft of the manuscript, CNA and NMC managed the analysis of the study. Authors NCI and DSM did the statistical analysis. UVCS and OU were incharge of logistics. Authors NCB, ECO and IMC managed the literature searches, and ALA, and IGI did the proof-reading. All the authors read through the manuscript and approve the publication.

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Data availability statement

All data generated or analyzed during this study are included in this published article.

CONFLICT of interest

All the authors declare that there is no conflict of interest and agreed to the publication of the work.

References

1. Achuba (2006). Avaliação de variações bioquímicas em moluscos bivalves em resposta ao estresse ambiental. Tese de Doutorado, Universidade de São Paulo, São Paulo.
2. Adam & Duncan (2002). Remediation of oil polluted soils: Effects of organic and inorganic nutrient supplements on the performance of maize. Water, *Air and Soil Pollution*. 66:59– 76
3. Adenipekun, C. O., Kassim, L.Q & Solomon O.U., (2009) Microbial quality of fruits and vegetables sold in Sango, Ota, Nigeria. *African Journal of Food Science* 4(5)
4. Agbogidi, O.M., & Ejemeta, O.R., (2005). An assessment of the effect of crude oil pollution on soil properties, germination and growth of Gambaya albida (L). *Uniswa Research Journal of Agricultural Science and Technology*. 8(2):148-155.
5. Aguair, J. L., McGiffin, M., Natwick, E. & Takele, E. (2011). Okra production in California. *UC Vegetable Research and Information Center*. Available at: http://anrcatalog.ucdavis.edu/pdf/7210.pdf.
6. Akpokodje, O.I, Uguru, H. & Esegbuyota, D. (2018) Evaluation of phytoremediation potentials of different plants' varieties in petroleum products polluted soil. *Global Journal of Earth and Environmental Science;* 4(3):41-46.
7. Al-Baldawi, I.A., Abdullah, S.R.S., Anuar, N., Suja, F., Mushrifah, I., (2015). Phytodegradation of total petroleum hydrocarbon (TPH) in diesel-contaminated water using Scirpus grossus. *Ecological Engineering*. 74: 463–473.
8. Allen, (1988). Assessing Compliance with Food Hygiene Requirements among Urban and Sub-urban classified hotels In Bauchi State, Nigeria. Kenyatta University
9. Anolufo, F., Gómez, P. A., & Artés-Hernández, F., (2006). Physical, Physiological and Microbial Deterioration of Minimally Fresh Processed Fruits and Vegetables. *Food Science and Technology International*, 13(3), 177–188. doi:10.1177/1082013207079610.
10. Asuquo, M., Usall, J., Anguera, M., Solsona, C., & Viñas, I. (2001). Microbiological quality of fresh, minimally-processed fruit and vegetables, and sprouts from retail establishments. *International Journal of Food Microbiology*, 123(1–2), 121–129. doi:10.1016/j.ijfoodmicro.2007.12.013
11. Ekundayo, J.A., Aisueni, N., Benka-Coker, M.O., (2009). The effects of drilling fluids in some waste and burrow pits in western operational areas of Shell Petroleum Development Company of Nigeria Limited on the soil and water quality of the areas. Environmental Consultancy Service Group, Consultancy Services Unit, University of Benin, Benin City, Nigeria;
12. G O. Anoliefo and D. E. Vwioko (2005). Removal of sorbed polycyclic aromatic hydrocarbons from soil, sludge and sediment samples using the Fenton's reagent process. *Chemosphere*. 59, 1427–1437.

13. Grossman, R.B and Ranches, T. G. (2002). Bulk density and linear extensibility in: Dane, J.H., Topp. G.C (*eds*) Pp: 45-48
14. Henner, Peijnenburg, W.J.G.M. & Hendriks, A.J. (2201). Bioaccumulation of heavy metals in terrestrial invertebrates. *Environmental Pollution*. vol.113, no.3, pp. (385- 393), ISSN 02697491
15. Kuiper, A. M.O., Oboh, B.O., (2009). Phytoremediation of crude oil contaminated soil: the effect of growth Glycine max on the physio-chemistry and crude oil content of soil. *Nature and Science*. 7(10):79- 87.
16. Moratova, M.; Foschi, J.; Rosmini, R.; Marin, M.G. and Serrazanetti, G.P. (2003). Heat shock protein 70 response to physical and chemical stress in Chamelea gallina. *Journal of Experimental Marine Biology and Ecology*, vol.397, pp.(71-78), ISSN 00220981
17. Nelson, D.W & Sommers L.E (1991). Total Carbon, Organic Carbon and Organic Matter in: Sparks D.L. (Eds), Methods of Soil Analysis part 3. *Chemical methods*, No 5 ASA and SSSA, Maddian, Wi, Pp. 061-1010
18. Nelson, D.W & Sommers L.E (1982). Total Carbon, Organic Carbon and Organic Matter in: Sparks D.L. (Eds), Methods of Soil Analysis part 3. SSSA Books series No 5 SSSA
19. Samina, R.; Shukla, N.; Jabeen, S. & Saxena, P. K. (2001). Pollution effect of distillery on the growth behavior of Phaseolus radiates L. Environmental Pollution. vol.37, pp.(245-243), ISSN 02697491
20. Bundy, R.; Fattorini, D.; Pisanelli, B.; Macchia, S.; Oliviero, L.; Pilato, F.; Pellegrini, D. & Regoli, F., (2002). Contamination accumulation and biomarker responses in caged mussels, Mytilus galloprovincialis, to evaluate bioavailability and toxicological effects of remobilized chemicals during dredging and disposal operations in harbour areas. *Aquatic Toxicology*, vol.89, pp.(257-266), ISSN 0166445X.
21. Quinone Aquilar, Gebrehiwot M., & Zinabu Teka (2003) Food safety knowledge, attitude and associated factors of food handlers working in substandard food establishments in Gondar town Northwest Ethiopia. *International Journal of Medical and Health sciences Research* 1(4): 37-49.
22. Wang, J., Jiq C.R., Wong C.K., Wong P.K., (2000). Characterisation of polycyclic aromatic hydrocarbons created in lubricating oils. *Water, Air and Soil Pollution*, 120: 381-396.
23. Welding & Dress (1983). Mutagens in contaminated soil: a review. *Mutation Research*, vol.567, pp.(227-345), ISSN 13835742 .