Contagion of Rudimentary Oil on Soil Physical Attributes, Yield of Soybean and Fresh Weight of Soybean Pods

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Abstract
Contagion of rudimentary oil on physical attributes and yield of soybean (Glycine max (L) Merr.) was assessed in three locations zones of Delta State (Isoko North, Ughelli North and Warri South Local Government Areas) Nigeria. Soil properties evaluated were particle size distribution, bulk density, total porosity, moisture content and hydraulic conductivity were obtained through summation method conductivity. Data were subjected to analysis of variance. The research work was performed in a CRD formation (Completely Randomized Design) divided into 3 segments. Depth of soil was collected from 0 – 30 cm in each population to determine both pre and post physical analysis. Core samplers (3.143 cm^3) were filled with soil to determine all the soil physical attributes studied. Results showed that contagion of rudimentary oil to soil physical properties studied were negatively affected as well as yield variables (fresh weight of pods and number of pods) significantly. Results showed that sand, silt and clay ranges from 67.88–75.53, 14.00-15.54 and 14.33-16.96 %, for uncontaminated soil and 66.66-69.83, 9.81-14.17 and 14.66-19.17 for contaminated of all the study area (Uzere, Ugheliand and Warri). Bulk density, total porosity and macro porosity in these area ranges from 1.33-1.37, 49.81-55.62 and 44.33-44.99 for uncontaminated soils and for contaminated soils were ranged in the following order; 1.41-144, 40.73-46.70 and 34.93-41.23 %. Micro porosity, hydraulic conductivity and moisture content ranges from 3.30-5.80, 14.56-34.80 and 15.90-18.13 for uncontaminated soils while contaminated soils have its ranges from 6.80-10.72, 6.33-9.06 and 6.06-8.33 respectively for Uzere, Ugheliand and Warri.

Keywords: *Crude oil contamination, soil properties, heavy metals, growth and yield, soybean*.

Introduction

The Niger Delta region of Nigeria including Isoko South, Ugheli North, and Warri South remains one of the highest petroleum-impacted agricultural zones in Africa due to decades of crude oil exploration, transportation, vandalism, spills and artisanal refining activities. Continuous release of petroleum hydrocarbons into the environment has led to pervasive contamination of soil and water, with significant implications on environmental quality and rural livelihoods reliant on crop production (Onyiba, *et al.,* 2024). Soil contamination by hydrocarbons and oil derivatives alters the soil environment in ways that degrade its biological, chemical, and physical properties. Hydrocarbons coat soil particles, reduce porosity, impede water infiltration and aeration, and interfere with nutrient cycling collectively impairing the soil's ability to support healthy plant growth (Akinkpelumi, *et al.,* 2025). In agricultural landscapes, these changes significantly affect crop germination, growth, and yield. Among staple and cash crops grown in southern Nigeria, soybean (Glycine max (L.) Merr.) is particularly important due to its nutritional and economic value, being a major source of protein and vegetable oil. However, its response to petroleum hydrocarbon pollution, especially in Nigeria's Niger Delta, remains under-studied compared to cereals and vegetables (Osibemhe, *et al.,* 2025).

Soil physical attributes including water infiltration, bulk density, porosity, hydraulic conductivity, soil texture and moisture retention are fundamental determinants of soil quality and plant growth. When soils are contaminated with oil or hydrocarbon residues: Porosity and infiltration can decrease, limiting water movement and root penetration. Hydraulic conductivity often declines, reducing soil water availability to crops. Soil surfaces can become hydrophobic, encouraging runoff and erosion rather than infiltration. Soil compaction tends to increase, further restricting root growth and nutrient uptake. These physical changes have been widely observed in studies on spent engine oil and petroleum contaminated soils cultivated with various crops, including soybean (Akinkpelumi, *et al.,* 2025) for example, research on ultisol soils planted with soybean showed that spent engine oil contamination reduced soil infiltration rates drastically and lowered saturated hydraulic conductivity compared to uncontaminated controls. At higher pollution levels (2–3% v/w), infiltration and water movement were severely limited, leading to reduced plant establishment and poorer growth performance. Studies by Odiyi, *et al.,* (2020) has shown that crude oil displaces air from soil particles and lead to insufficient aeration that reduced soil microbial activities. It can clog soil particles thereby reducing water infiltration and increasing bulk density. It also results to hard pan formation beyond the depth of 15cm which can hinder root penetration and consequently affect plant growth. Ifediora *et al.,* (2018) reported that waste oil causes a breakdown of soil texture, followed by soil dispersion. He also reported that the presence of fresh crude oil had coagulator's effects on the soil, binding the soil particles into a water impregnable soil block, which seriously impair water drainage and oxygen diffusion. He further stated that seeds sown in such soil failed to germinate. Soybean (G. max) is a major leguminous crop widely cultivated for its high protein and oil content. Petroleum contamination can be phyto-toxic to soybean by several mechanisms: Impaired seed germination, inhibition of root and shoot growth, altered nutrient uptake, induction of stress responses such as oxidative damage. Studies involving soybean grown in soils contaminated with spent engine oil demonstrate significant reductions in germination and growth parameters at higher contamination levels, with poorer biomass accumulation and lower grain yield compared to uncontaminated soils (Ahamefule, *et al.,* 2017). In contrast, at very low levels of contamination (e.g., 1% spent auto-engine oil), some studies have reported slight stimulation of growth attributes, suggesting that dose and contamination type play critical roles in determining plant response (John and Rashida, 2024). Beyond its economic value, soybean has been studied as a Phytoremediation agent capable of assisting in the breakdown or transformation of petroleum hydrocarbons through root–microbe interactions. While older research, Njoku *et al.,* (2016) has demonstrated improved soil properties and reduced Total Petroleum Hydrocarbon (TPH) levels in soybean-planted treatments, these findings support the idea that Glycine max may play a dual role: both as a crop and as a cleaner of contaminated soils (Jaja, 2023). Oil exploration and production in the Niger Delta including Isoko South, Ugheli North, and Warri South contributes substantially to Nigeria's economy. However, this comes at a high environmental cost. Frequent crude oil spills, pipeline leaks, and rudimentary refining have left large tracts of farmland contaminated with petroleum hydrocarbons (Hauane da, *et al.,* 2022). These contaminants alter soil physical and chemical characteristics, reduce fertility and biological activity, inhibit crop germination and growth, undermine farmers' livelihoods dependent on crop production. Most soil chemical properties determine the nutrient availability and also the breakdown the movement of pollutants in the soil. This implied that the crude oil decrease soil pH which implies that the soil will become acidic. This acidic nature may react with soil salts and minerals and change the alkaline minerals to acidic. This could negate the solubility of plant minerals thus resulting to lower level of nutrient availability of plants (Umukoro, *et al.,* 2022). Despite this, there is limited localized research on how rudimentary oil contamination affects soil physical characteristics and soybean performance specifically. Without such data, it is difficult for policymakers, extension workers, and agronomists to implement effective remediation or sustainable farming practices in contaminated landscapes. Understanding how rudimentary oil contamination affects soil physical properties and soybean growth in Isoko South, Ugheli North, and Warri South is critical for several reasons like food security**.** Soybean is a key source of protein and vegetable oil for local farmers; pollution-induced yield losses threaten household food supply. Soil health monitoring as quantifying physical soil changes informs soil management and remediation strategies necessary for restoring productivity (Jarikre and Onyibe, (2026). Sustainable agriculture informs of Identifying contamination thresholds where soybean growth remains possible can help farmers make informed cropping decisions in polluted zones. Policy and remediation data on local contamination impacts will guide targeted environmental remediation and agricultural policy in the Niger Delta. Despite studies in controlled or university settings, data specific to crude oil contamination impacts in Isoko South, Ugheli North, and Warri South on soil physical attributes and soybean growth is sparse. These areas are significant oil production and spill zones but lack concentrated agronomic research. Thus, empirical investigation is needed to quantify local contamination levels, soil property changes, and soybean response under field conditions. The main objective of this study was to assess the contagion of rudimentary oil on soil physical attributes, yield of soybean and fresh weight of soybean pods in Isoko South, Ugheli North, and Warri South

Materials and Methods

Description of study area

Isoko South (Uzere), Ughelli North (Eruemukohwarien) and Warri South (Iffie-Kolo) are the three Local Government Areas where contagion of rudimentary oil regularly occurs in the oil producing areas of Delta State within the Niger Delta geo-political zone of Nigeria. Isoko South is located between Latitude $8^0\ 43^1$ N and Longitude $32^0\ 13^1$ E, Ughelli North is located between Latitude 5º 33^1 N and Longitude 5º 60^1 E and Warri South is located between Latitude 5º 50^1 N and Longitude 5º 76^1 E (Mindat.org. 2025). Average annual rainfall of the research zone is about 3750mm, mean annual temperature of 23ºC to 34ºC and average relative humidity of 90% to 95% and the terrain of the topography is plain terrain of average altitude of about 6.5 m over sea level (Oyebiyi, *et al.,* 2024). The soybean seeds (TCiX 1445 – 2E) an early maturing selection of 90 – 100 days were secured from IITA, Ibadan.

Field Technique/Survey methodology

The field work commenced with a reconnaissance visit to different Local Government Areas (LGAs). Based on the preliminary investigation, areas affected by oil spillage were identified. A semi-detailed survey was carried out to select areas that are constantly polluted/contaminated. Based on this, three Local Government areas and communities namely: Isoko South (Uzere community), Ughelli North (Eruemukowarien community) and Warri South (Iffie-Kolo community) were selected.

Collection of soil samples

In each town, representative composite soil samples were collected at a depth of 0 – 20 cm with the aid of soil auger from areas affected by oil contamination to about 50 meters to areas not affected (unpolluted) to determine pre and post physical properties.

Design of the Experiment

The research work was arranged in a CRD (Completely randomized design) formation, consisting of 6 treatments (T1 = uncontaminated control soil, T2 = contaminated soil, T3 = uncontaminated control soil, T4 = contaminated soil, T5 = uncontaminated control soil and T6 = contaminated soil) and were segmented 3 times were T1 uncontaminated control soil and T2 contaminated soil representing soil samples from Isoko LGA site. T3 uncontaminated control soil and T4 contaminated soil, representing samples from Ughelli North LGA site and finally, T5 uncontaminated control soil and T6 contaminated soil, representing samples from Warri South LGA respectively.

Physical properties experimented and methods

To assess the contagion of rudimentary oil on soil physical properties, a representative soil samples were collected from contaminated and un contaminated sites at a depth of 0 – 35 cm. The samples were collected at wet weighed and recorded, also air-dried and also recorded for their physical properties like particle size distribution, bulk density, total porosity, moisture content, saturated hydraulic conductivity and soil aggregate stability. Particle size distribution was determined using a method described by Zhang, *et al.,* (2020) and textural class was obtained using a method developed by Mathewos, (2024)

Bulk density and particle density was determined based on the procedure developed by Rodríguez-López, *et al.,* (2025) while total porosity was evaluated based on bulk density relation assuming a particle density of 2.65 gcm^{-3}. Saturated hydraulic conductivity was obtained according to the method described by Kargas, *et al.,* (2022). Soil moisture content was determined using gravimetric method

Agronomic parameters studied

Data for yield variables (Number of soybean pods and weight of soybean pods) were collected and calculated at harvest.

Data Analysis

The data collected were subjected to Analysis of variance (ANOVA) and means separated using Least Significant Difference (LSD) test at 0.01 and 0.05 level of probability

Results and Discussion

Contagion of rudimentary oil on soil physical properties

Table 1: Low, Medium and high rating for discussing most soil physical properties

Soil properties	Low	Medium	High
Sand (%)	<30	30-70	>70
Silt (%)	<15	15-40	>40
Clay (%)	<15	15-30	>30
Bulk density (gcm^{-3})	<1.3	1.3-1.6	>1.6
Porosity (%)	<40	40-50	>50
Water holding capacity (%)	<20	20-35	>35

Source: USDA (2022)

Particle size distribution

Soil physical properties of the studied areas are shown in Table 2, 3 and 4. Texturally, the soil classes are sandy loam for both uncontaminated (control) and contaminated soils based on USDA (2022). Slightly significant differences ($P > 0.05$) was found in particle size distribution (Sand) in all the studied site for contaminated and uncontaminated (control). Isoko - Uzere uncontaminated soil had the highest percentage of sand with 75.53 % compared with the contaminated (control) with 69.83 %. Ughelli (Eruemukowarien) uncontaminated had 73.20 %. As highest compared with its contaminated 68.0%. Similarly, Warri (Iffie) uncontaminated had a value of (67.88 %) for sand compared with contaminated soil of 66.66%. The above findings corroborate Palazot *et al.,* (2024) who reported no significant effect in crude oil pollution on granulometric fraction of the soil. Isoko (Uzere) location has the highest sand content, invariably having the highest rapid water hydrocarbon infiltration and lowest water/hydrocarbon holding and very low nutrient storage capacity resulting in high carbon/nitrogen ratio. According to the USDA (2022) reported that soil textural values for uncontaminated and contaminated of the studies soils ranges from medium to high (Table 1). There was significant differences ($P < 0.05$) in silt distribution in uncontaminated (control) and contaminated in Isoko (Uzere) with 15.84% for the uncontaminated (control) and 9.81% for contaminated soil and had slightly differences between in Ughelli (Eruemukowarien) and Warri (Iffie). Silt was 14.00% for uncontaminated and 11.10 % for contaminated soils in Ughelli (Eruemukowarien) while Warri (Iffie) silt content for uncontaminated soil was 15.16 % and 14.17% and for uncontaminated and contaminated soils. Generally, Tables 2, 3 and 4, were rated as low to medium (Table 1). The effect of crude oil contamination on the studied soils indicated that crude oil slightly affected silt content of the soil. A similar result was obtained by Carrascosa *et al.,* (2025) who observed in a crude oil polluted area that granulometric fraction of the soil was influenced by the presence of crude oil. Values for clay in Isoko (Uzere) uncontaminated and contaminated soils had no significant differences ($P> 0.05$) and was slightly different in the other sites. Isoko (Uzere) uncontaminated had the lowest percentage of clay with 14.33% and 14.66 % for contaminated soils. Ughelli (Eruemukowarien) uncontaminated is 15.70 % clay and 18.00 % clay for contaminated soil. Warri (Iffie) had the highest percentage of clay with 19.17 % for contaminated soil and 16.96% for uncontaminated soils. The soil characterization agrees with the findings of Olasunkanmi, *et al.,* (2024). This observation also is in harmony with earlier report of Chukwu, *et al.,* (2024) who noted that oil in soil has deleterious effects on the physical properties depending on the dose, type of the oil and other factors.

Bulk Density and Total Porosity

Significant levels at *(P>0.05)* for all the physical properties studied are shown in Tables 2 – 4. As regards all the physical properties studied as stipulated in to Tables 2 – 4, bulk density in IsokoUghelli (Eruemukowarien), ranges from 1.33 – 1.41 gcm^{-3}, in Ughelli (Eruemukowarien), was 1.37-1.43 gcm^{-3} and in Warri (Iffie) was 1.33 – 1.44 gcm^{-3} with increasing order reading from uncontaminated to contaminated soils. Total porosity range in Isoko (Eruemukowarien), was 49.81 – 46.70 %, Ughelli (Eruemukowarien), was 55.62 – 40.73 % while Warri (Iffie) was 49.81 – 45.70 % with decreasing order reading from uncontaminated to contaminated soils.

The above findings is also in agreement with (Jarikre and Onyibe, 2026., Oyem and Oyem, 2024., Moore, *et al.,* 2025). In their related findings, it was observed that these state of soils can actually support plant growth and perform best in bulk densities below 1.40 - 1.6 gcm^{-3} for soils respectively

Macro and micro porosity

Macro porosity of the studied sites indicated that its values for uncontaminated sites were increasing with 44.33, 44.90 and 44.46 % while micro porosity for the same uncontaminated areas decreased as follows 3.47, 5.80 and 3.30 %. On the other hand, macro porosity for contaminated areas decreased compared to that of the uncontaminated areas with 35.46, 34.93 and 41.23 %. Also, in comparison with micro porosity for uncontaminated areas, values for micro porosity for contaminated areas, were higher with 6.80, 10.72 and 6.99 % for Isoko (Eruemukowarien), Ughelli (Eruemukowarien) and Warri (Iffie) respectively. However, similar results were obtained for uncontaminated and contaminated soils thus, agreeing with similar findings of Moore, *et al.,* (2025). The result showed that macro porosity of the soil decreased in the crude oil contaminated soil. This result is an evidence of clogging of the pore spaces with crude oil and this can impede air and water flow in the soil.

Hydraulic conductivity and moisture content

Hydraulic conductivity for uncontaminated areas for the three studied sites (IsokoUghelli (Eruemukowarien), Ughelli (Eruemukowarien) and Warri (Iffie) were 34.80, 14.56 and 26.0 cm sec^{-1} while values rated for contaminated areas were 9.06, 8.80 and 6.23 cm sec^{-1}. The findings in Tables 2 – 4, thus shows that locations having uncontaminated soils are in the moderately rapid conductivity class to rapid conductivity class than contaminated areas (Oku *et al.,* 2021). Thus result may be due to the blockage of pores with the crude oil debris. Moisture content for uncontaminated areas, ranges from 15.90 – 7.16 % in Isoko (Eruemukowarien), 17.06 – 8.33 % in Ughelli (Eruemukowarien) and 18.13 – 6.06 % in Warri (Iffie) with decreasing order from uncontaminated to contaminated areas respectively. A significant moisture content reduction ($p<0.05$) in the contaminated soil compared to the uncontaminated soil was observed. This implies that crude oil contamination reduced soil moisture availability in the contaminated soils thus reducing plant growth and yield (Moore, *et al.,* 2025).

Table 2: Effects of crude oil contamination on soil physical properties in Isoko (Uzere)

Soil Variables	Uncontaminated	Contaminated	LSD*(P>0.05)*
Sand (%)	75.53	69.83	*
Silt (%)	15.84	9.81	**
Clay (%)	14.33	14.66	ns
Textural class	S.L	SL	

B^d (gcm^{-3})	1.33	1.41	*
T^p (%)	49.81	46.7	*
Macro porosity (%)	44.33	35.46	**
Micro porosity (%)	3.47	6.80	*
Ksat (cm/s)	34.80	9.06	**
Gravimetric moisture content (%)	15.90	7.16	**

SL = Sandy loam; B^d = Bulk density; P^d = Particle density; T^p = total porosity; Ksat = Saturated hydraulic conductivity, *slightly significant, **highly significant.

Table 3: Effects of crude oil contamination on soil physical properties in Ughelli (Eruemukowarien)

Soil Variables	Uncontaminated	Contaminated	LSD*(P>0.05)*
Sand (%)	73.20	68.00	*
Silt (%)	14.00	11.10	*
Clay (%)	15.70	18.00	*
Textural class	S.L	SL	
B^d (gcm^{-3})	1.37	1.43	*
T^p (%)	55.62	40.73	*
Macro porosity (%)	44.90	34.93	**
Micro porosity (%)	5.80	10.72	**
Ksat (cm/s)	14.56	8.80	**
Gravimetric moisture content (%)	17.06	8.33	**

SL = Sandy loam; B^d = Bulk density; P^d = Particle density; T^p = total porosity; Ksat = Saturated hydraulic conductivity, *slightly significant, **highly significant.

Table 4: Effects of crude oil contamination on soil physical properties in Warri (Iffie)

Soil Variables	Uncontaminated	Contaminated	LSD*(P>0.05)*
Sand (%)	67.88	66.66	ns
Silt (%)	15.16	14.17	ns
Clay (%)	16.96	19.17	*
Textural class	S.L	SL	
B^d (gcm^{-3})	1.33	1.44	*
T^p (%)	49.81	45.70	*
Macro porosity (%)	44.46	41.23	ns
Micro porosity (%)	3.30	6.99	*
Ksat (cm/s)	26.76	6.23	**
Gravimetric moisture content (%)	18.13	6.06	**

SL = Sandy loam; B^d = Bulk density; P^d = Particle density; T^p = total porosity; Ksat = Saturated hydraulic conductivity, *slightly significant, **highly significant.

Contagion of rudimentary oil on number of pods of soybean and weight of soybean pods at harvest

Number of pods for Isoko-Uzere ranged from 74.33 % (contaminated sites) to highest of 121.63 % (uncontaminated control sites) of all the studied sites. For Ughelli-Eruemukowarein, ranged from 23.46 % (contaminated sites) to 86.40 % (uncontaminated control soils) while in Wari-Iffie under contaminated soils, ranges from 20.66 % to 69.83 % for (uncontaminated control sites) and there was high variation between the two sites (Tables 2 – 4). Weight of soybean pods for Isoko-Uzere, Ughelli-Eruemukowarein and Wari-Iffie under contaminated and uncontaminated control sites were registered as follows; 21.90 to 50.46 kg/plot, 15.46 to 43.20 kg/plot and 17.36 to 21.59 kg/plot (Tables 2 – 4) with high variation between contaminated and uncontaminated control sites for all the studied sites. . From the above findings, it can be deduced that the poor performance of soybean plants whose seeds were sown in contaminated soil compared to the seeds sown in uncontaminated soil was an indication of the deleterious effects of crude oil on plant growth (John and Rashida, 2024).

Table 5: Contagion of rudimentary oil on pod yield of soybean and fresh weight of soybean pods at harvest

Variables	Isoko uncontaminated	Isoko contaminated	Ughelli uncontaminated	Ughelli contaminated	Warri uncontaminated	Warri contaminated
Number of soybean pods	121.63	74.33	86.40	23.46	69.83	20.66
weight of soybean pods	50.46	21.90	43.2	15.46	21.59	17.36
CV %	20.51	21.06	14.29	12.15	17.32	19.81
LSD (0.05)	4.28	13.16	10.17	8.69	13.08	20.04

Conclusion

Contagion of rudimentary oil on soil physical attributes, number of soybean pods and weight of soybean pods was studied in Isoko South, Ugheli North and Warri South. The Contagion of rudimentary oil on soil harmfully influences soil physical attributes, soybean yield, and the fresh weight of soybean pods. Contagion of rudimentary oil modifies vital soil properties such as porosity, permeability, bulk density, water infiltration, and aeration, thereby dropping down soil fertility level and generating harsh conditions for plant growth. These modification, limit root development, nutrient uptake, and water availability, which are essential for most favorable soybean performance. As the level of Contagion of rudimentary oil increases, momentous diminutions are observed in soybean growth, grain yield, and fresh pod weight. Petroleum hydrocarbons attached with the deterioration of soil structure, impair physiological development such as photosynthesis and nutrient metabolism, resulting in poor crop productivity. Apparently, Contagion of rudimentary oil on soils become less suitable for sustainable agricultural production. Therefore, effective management and remediation of oil-polluted soils are necessary to restore soil quality, enhance soybean growth, and improve crop yield.

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