EFFECTS OF CRUDE OIL CONTAMINATION ON SOIL CHEMICAL PROPERTIES IN DELTA STATE, NIGERIA.

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ABSTRACT
Crude oil contamination on soil chemical properties was evaluated in Isoko North, Ughelli North and Warri South Local Government Areas(LGAs), Delta State, Nigeria. The experiment was laid out in a completely randomized design (CRD) with 6 treatments replicated three times. The objective was to investigate the effect of crude oil contamination on soil chemical properties in three soil zones. Soil samples were taken at a depth of 0 – 15cm in each community for chemical analysis. Soil chemical properties evaluated analyzed were, soil pH, electrical conductivity, organic carbon, total nitrogen, available phosphorus, exchangeable cations, exchangeable acidity, Effective cation exchange capacity and Base saturation. Data were subjected to Analysis of Variance. Results showed soil pH, organic carbon, available phosphorus, exchangeable cations, exchangeable acidity, effective cation exchange capacity and base saturation and these chemical properties evaluated and analyzed increased significantly under uncontaminated soils except that total nitrogen and electrical conductivity were highest with (0.28 g kg^{-1} and 64.4000$\pm$9.9), (0.26 g kg^{-1} and 63.3333$\pm$7.9) and 0.29 g kg^{-1} and 62.4337$\pm$8.2) successively for lsoko(Uzere), Ughelli and Warri (Iffie) in contaminated soils.

Keywords: Crude oil, Contamination, Uncontaminated, Soil chemical properties, Community
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INTRODUCTION
Soil is the most valuable component of the earth ecosystem that human and animal sustainability largely depends on. Its sustainable use is absolutely necessary for agricultural productivity (Oyedeji, *et al*., 2012). Lands are usually acquired in the process of oil exploration for pipeline laying and construction of platforms and flow stations while in the process, soil properties such as biological, chemical and physical properties are altered leading to environmental hazard (Irhivben, *et al*., 2013). Environmental pollution is a common hazard in the Niger-Delta region largely due to crude oil exploration. The activity of man associated with crude oil exploration on agricultural land has its economic disadvantages where crude oil are being drilled. For instance, fertile lands used to produce food are now infertile and this has threatened sustainable food production (O'Rourke and Connolly, 2003). Contamination of agricultural land is a major problem in oil producing nations. Even non-oil producing nations that depend on supply through cross country underground and sea transportation are not secured due to accidental spillages. Oil spills have led to land deterioration and loss of soil fertility.

Soil contamination is the anomalous concentrations of toxic substances. It is also a serious environmental concern since it harbors many health hazards. For example, exposure to soil containing high concentrations of benzene increases the risk of contracting leukaemia. Soil contamination occurs when human-made chemicals, such as hydrocarbons and heavy metals, find their way into the earth, altering the natural soil environment (Marie, 2022). Generally, soil contamination is cited as a consequence of non-organic farming practices, industrial activity and improper waste disposal. Common chemicals involved in soil contamination include petroleum hydrocarbons, lead, solvents, pesticides and poly nuclear aromatic hydrocarbons, such as naphthalene. A contaminant can be considered a pollutant when the concentration is high enough to cause harm to the ecosystem. Pollution inform of contamination, has been known as one of the negative effects of human technological advancements which has drastically destroyed lands and water bodies. Crude oil pollution has been estimated to be over 80% as a result of spillage Ewetola, (2013). Crude oil contamination decreases nitrogen and phosphorous contents, provides excessive hydrocarbon which affect soil enzymatic activities and soil physical properties such as pore spaces are clogged thereby reducing soil aeration, infiltration rate and increased bulk density that affect plant growth including formation of hard pan which can hinder root penetration (Eluehike, *et al*., (2009) and (Ewetola, 2013). Presently, some leguminous crop like soybean, has been discovered to moderately grow in crude oil contaminated soil due to their high nutrient of protein and oil content and is commercially cultivated.

Soybean is extremely an important crop for soil improvement and management. Soybean have also been discovered very useful in the production and manufacturing industries apart from its use for local consumption. Although, crude oil spills is common in the Niger-Delta region, impact of menace has not been widely studied, it is therefore important to study the effects of crude oil contaminated soils, on soil physico-chemical properties and on the growth and yield of soybean (*Glycine max (L) MERR*) in Delta State.

MATERIALS AND METHODS

Description of study area

The study was performed in three Local Government Areas of Delta State, within Niger-Delta geo-political zone of Nigeria namely Isoko South (Uzere community), Ughelli North (Eruemukowarien community) and Warri South (Iffie-kolo community) where crude oil contamination is at regular occurrence. Isoko is located on latitude 8^0 41^1N and Longitude 31^0 12^1E, Ughelli North is located on 5^0 30^1N and Longitude 5^0 59^1 while Warri South is located on Latitude $5^0 52^1$N and 5^0 75^1E (NIMET, 2018). The study areas have an average annual rainfall of about 3840 mm, mean annual temperature of 20^0C to 35^0C and average relative humidity of 92% to 96% (NIMET. 2018). The topography is a flat terrain of average height of about 6m above sea level (Efe, 2005).

Sample collection

In each LGA of the oil contaminated soils, representative composite soil samples were collected at a depth of 0 – 15cm using soil auger while the same depth and instrument was used in areas not affected (unpolluted) which served as control.

Establishment of experimental sites/ Experimental design

Sites measuring 60m x 30m were cleared of bushes and debris were removed after which polythene bags containing soils of contaminated and uncontaminated were kept on the surface of the plots for the periods of the experiment within the three L G A of Delta State. The size of each plot was 15m × 15m and was separated from each other with a space of 2m. The experimental design was Completely Randomized Design (CRD) consisting of 6 treatments (T_1c, T_{2p}, T_3c, T_{4p}, T_5cand T_{6p}) and replicated 3 times. T_1c, T_{2p} representing soil samples from Isoko LGA site (c for control and p for contaminated soil), T_3c,, T_{4p} representing samples from Ughelli North LGA and T_5c,, T_{6p} representing samples from Warri South LGA, respectively.

Chemical analysis

Soil pH in both water and KCl using digital pH-meter (Mclean, 1965). **Organic carbon** was determined by Dichromate wet oxidation method of Walkley and Black. **Total Nitrogen** was determined by Micro kjeldahl procedure (Bremmer, 1982). **Available phosphorus** was determined by Olsen method (Emtenydy, 1989). **Exchangeable cations** (Ca, Mg, K, Na) was extracted with neutral Ammonium acetate (NH_4OAC) pH 7. Potassium (K) and Sodium (Na) in the extract were determined using the auto-electric flame photometer, and Magnesium (Mg) by the Atomic Absorption Spectrophotometer (IITA, 2013). **Exchangeable Acidity** (Al + H) was extracted with Potassium chloride (KCl) and determined titrimetrically with 0.001 N NaOH (McLean, 1965). **Cation exchange capacity** (CEC) was determined using a neutral solution of ammonium acetate leaching at pH 7.0 (Rhodes, 1982). **Effective cation exchange capacity** (ECEC) was ascertained by summation of Total Exchange Bases and Total Exchangeable Acidity i.e ECEC = TEB + TEA. **Percent base saturation** (% B.S): This was determined by summing all the base forming cations and dividing by the values of ECEC multiplied by 100%.

$$\%B.S = \frac{Sum of all base forming cation}{ECEC} \times 100$$

Data Analysis

Data collected for chemical attributes were subjected to one way analysis of variance (ANOVA) and treatment means were separated using Least Significant Difference (LSD) test at 0.01 and 0.05 levels of probability with SAS software version 9.0

RESULTS AND DISCUSSION

Effects of Crude Oil Contamination on Soil Chemical Properties

Soil pH: The pH of the soils ranged from 5.63 - 6.40 (Isoko-Uzere), 5.56 – 6.64 (Ughelli-Eruemukowarien) and 5.70 – 6.56 (Warri-Iffie) successively from contaminated to uncontaminated (Table 3-5). Soil pH determines the nutrient availability and also the breakdown and movement of pollutants in the soil. It 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 (Ojobor *et al*., 2021). Low pH affects soil microbial behavior and this affect the breakdown of organic material that releases nutrients for plant absorption (Oyem and Oyem, 2013). The values measured in the experimental areas for control (uncontaminated) ranging from 6.4 – 6.5 are not detrimental to crop plant as high agricultural productivity can be obtained in soils with pH up to 6.5 (FAO, 1976). In natural soils, treated with most organic wastes like burnt yam peels can increase soil pH to a certain values of 6.2 which is not also injurious to crops (Onyibe *et al.*, 2021).

Redox Potential (e^H): There were significant differences (P > 0.05) in the redox potential (e^H) of soil samples. As recorded in Table 3-5, across the three experimental areas studied. The redox potential decreased markedly in the crude oil contaminated soils. However, the recorded redox potential values which ranged from 732.33 mv to 744.00 mv for control (uncontaminated), 625.00 mv to 646.00 mv for crude oil contaminated soils agree with the findings of Uquetan *et al.* (2017) who reported that the values of 732.33 mv – 744.00 mv for uncontaminated soils are all well-oxidized soils. Ughelli (Eruemukowarien) had the lowest e^H value for contaminated soils with 625.00 mv. This location also had the lowest e^H value for uncontaminated soils with 732.33 mv. Kayode *et al*. (2009), Asuquo *et al*. (2001) have reported that the presence of some sulphur and vanadium compounds often present in trace amount in crude oil could increase the rate of chemical oxidation and redox potential values of oil contaminated soils.

Electrical conductivity (EC): The electrical conductivity (EC) ranged from 30.63 dsm^{-1} – 31.83 dsm^{-1} for uncontaminated (control) soils and 62.40 dsm^{-1}-64.40$dsm^{-1}$for contaminated soils in the studied areas. The result in Table 3-5 shows that the contaminated soils have high EC implying that the soil is saline in nature (Scherer, 1996). Warri (Iffie) had the lowest EC with 30.63 dsm^{-1} from uncontaminated soil and 62.43 dsm^{-1} for contaminated soil. The values however, showed that EC for contaminated soils were significant ($P < 0.05$) compared with the uncontaminated (control) locations. Observed results showed a remarkable increase in soil electrical conductivity in the three locations with crude oil contamination. Isoko (Uzere) having the highest EC with 64.40 dsm^{-1}, followed by Ughelli (Eruemukowarien) with an EC value of 63.33 dsm^{-1} and Warri (Iffie) with an EC value of 62.44 dsm^{-1}. Uquetan *et al*. (2017) reported that the increase in the EC is attributed to the accumulation of exchangeable bases in the oil polluted soil which further affects the ionic stability of the soil and conversely nutrient availability and uptake by crop plants. The values obtained from both soil indicates that the EC is in the medium range which is good for agricultural purpose.

Organic carbon: Organic carbon showed significant differences ($P < 0.05$) across the studied areas. Values of organic carbon ranged from 0.62 gkg^{-1} – 0.67 gkg^{-1} for uncontaminated (control) soils and 2.77 gkg^{-1} – 2.82 gkg^{-1} for crude oil contaminated soils. It was observed that Warri (iffie) had the highest value 0.67gkg^{-1} for uncontaminated (control) soils and also had the highest value 2.82 gkg^{-1} for contaminated soils. However, the contaminated soils had higher organic carbon content than the uncontaminated (control) soils. Distribution of organic carbon varied with locations under study. The concentrations of total organic carbon (TOC) were significantly different among locations ($P < 0.05$). Organic carbon in the soil is generally derived from biota, such as peat formation with time, plant fine roots turnover, microbial biomass and others. Wang *et al*. (2010), reported that oil contamination significantly increased the total organic carbon (TOC) contents most probably because of the much higher total petroleum hydrocarbon (TPH) concentration (upto 3%) in their study. However, the findings indicated that the observed values of organic carbon fall into the low category which is less than 10gkg^{-1} as reported by Parameshgoudal *et al.*, (2016).

Total nitrogen: Total nitrogen in the studied areas were invariably low with values, ranging from 0.16 – 0.18 gkg^{-1} for uncontaminated soils and 0.26 – 0.18 gkg^{-1} for uncontaminated soils. Low attributes for total nitrogen of this study, is in line with the rating values of FMA and NR (1990) in Table 6. Even though the observed values were considered low, yet, they were higher in contaminated soils than uncontaminated soils. Wang et al. (2009) reported that the increased values of total nitrogen are attributed to the impact of crude oil in promoting organic carbon content of the soil. Nitrogen dynamics and cycling in hydrocarbon contaminated soils may differ from those in uncontaminated agricultural soils because hydrocarbons can change soil physical, chemical and biological properties as reported by John *et al.*, (2011).

Available phosphorus: Available phosphorus (AP) showed significant differences (P < 0,05) across the studied areas. Isoko (Uzere) recorded 7.60 $mgkg^{-1}$ for uncontaminated soils and 5.0 $mgkg^{-1}$ for contaminated soil. Ughelli (Erumukowarien) recorded 7.54 $mgkg^{-1}$ for uncontaminated (control) soil and 5.0 $mgkg^{-1}$ for contaminated soil. Warri (Iffie) had 7.54 $mgkg^{-1}$ for uncontaminated soil and 5.24 $mgkg^{-1}$ for contaminated soil. From Table 3, the values of AP for contaminated soils ranged from 5.0 – 5.2 $mgkg^{-1}$ and 7.54 – 7.60 $mgkg^{-1}$ for uncontaminated (control) soils. Isoko (uzere) recorded the highest AP value with 7.60 $mgkg^{-1}$ for uncontaminated and also recorded the lowest AP value with 5.02 $mgkg^{-1}$ for contaminated soils respectively. Available P from the result obtained is classified low based on FMA & NR (1990) report in table 3d.However, available P values were generally low across the locations studied. This agrees with the findings of Egbuchua and Ojeifo (2007) who recorded low available P values for some hydric soils in the Niger Delta area and Ogboghodo *et al.*, (2004). The low values of available P recorded might be attributed to higher acidic nature across the locations with crude oil contaminated soils which can cause phosphorus fixation (Nkwopara *et al*., 2012).

Exchangeable calcium(Ca^{2+}) and Magnesium (Mg^{2+}): Exchangeable calcium (Ca^{2+}) and magnesium (Mg^{2+}) were generally moderate for all locations with contaminated soil. The results however showed significant difference ($P < 0.05$). There was reduction in

Ca^{2+} for crude oil contaminated soils as compared with uncontaminated (control). Calcium content ranged from 4.37 – 4.38 $cmolkg^{-1}$ for contaminated soils and 6.68 – 6.76 $cmolkg^{-1}$ for uncontaminated soils. FMA & NR (1990) gave the critical levels of calcium in soils for values less than 5$cmolkg^{-1}$ as low. Based on this rating in table 3d, the soils in the study areas are rated low in exchangeable calcium. Exchangeable magnesium (Mg^{2+}) showed no significant difference (P < 0,05). It ranged from 0.36 – 0.39 $cmolkg^{-1}$ for contaminated soils and 1.37 – 1.41 $cmolkg^{-1}$ for uncontaminated (control) soils table 3. Exchangeable Mg^{2+} is rated low in the soils of the studied location based on FMA & NR (1990) soil fertility rating in Table 6. Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) values were higher in uncontaminated (control) locations. This obviously implied that oil exploration activities negatively impacted these elements in the soils. Abii and Nwosu (2009) in their findings observed that basic cations are lost in soil with increasing acidity.

Exchangeable potassium (K^+) and sodium (Na^+): Exchangeable potassium (K^+) was low to medium for all soils across location investigated and there was no significant difference (P< 0.05). The result showed that K^+ content of contaminated soils were lower than that of uncontaminated soils. It ranged from 0.13 – 0.14 $cmolkg^{-1}$ for contaminated soils and 0.180 – 0.187 $cmolkg^{-1}$ for uncontaminated soils. The soils are rated low in exchangeable K based on FMA & NR (1990) soil fertility rating Table 6. Exchangeable sodium (Na^+) was moderate for all locations investigated. It however showed no significant difference (P < 0.05). It ranged from 0.14 – 0.18 $cmolkg^{-1}$ for crude oil contaminated soils and 0.27 – 0.30 $cmolkg^{-1}$ for uncontaminated (control) soils. Sodium (Na) is rated as low comparing the values with that of FMA & NR (1990) soil fertility rating in Table 6. Though sodium (Na) is not an essential element so it is not an index for optimum crop production (Abii and Nwosu, 2009).

Cation exchange capacity (CEC), Effective cation exchange capacity (ECEC), Exchangeable acidity and Base saturation.

Cation exchange capacity (CEC) and Effective cation exchange capacity (ECEC): The values of cation exchange capacity (CEC) and effective cation exchange capacity (ECEC) showed a general decreasing trend in the crude oil contaminated soils compared to the uncontaminated soils (Table 3-5). The CEC values ranged from 9.06 – 9.28 $cmolkg^{-1}$ for uncontaminated soils and 6.53 – 6.68 $cmolkg^{-1}$ for contaminated soils across location studies. The values obtained implies that the soils are classified low in CEC based on FMA & NR (1990) rating on soil fertility and also Udo *et al.*. (2009). Effective cation Exchange capacity has its values, ranged from 12.942 – 13.2467 $cmolkg^{-1}$ for crude oil contaminated soils while uncontaminated soils in the studied areas ranged from 7.5667 $cmolkg^{-1}$ – 7.6000 $cmolkg^{-1}$. In this study, crude oil contaminated soils has caused the reduction in EA and ECEC as also narrated by Agbogidi, *et al.*, (2007). Exchange acidity: Exchange acidity values in Table 3-5, for uncontaminated soils ranged from 4.40 – 4.61 $cmolkg^{-1}$ and 2.50 – 2.53 $cmolkg^{-1}$ for contaminated soils. Exchangeable acidity decreased in the crude oil contaminated soils across the locations investigated compared with those of the uncontaminated soils. The results however showed significant difference (P < 0.05). Exchangeable acidity as a function of the hydrogen and aluminum content of the soil was consistent in the values recorded across locations investigated. It ranged from 4.40 to 4.60 in uncontaminated soils and 2.50 to 2.53 in contaminated soils across locations investigated (Table 3-5). The above result is caused by the relationship existing between soil pH, organic carbon and exchangeable acidity (Chukwumatiz *et al*., 2019).

Base saturation (BS): Base saturation showed a significant difference (P < 0.05) in the crude oil contaminated soils across locations investigated. %BS ranged from 66.59 – 66.91% in crude oil contaminated soils and 66.23– 68.64%in uncontaminated soils. The %BS is classified as medium based on FMA & NR (1990) soil fertility rating (Table 6).

Table 3: Effects of crude oil contamination on soil chemical properties in Isoko (Uzere)

Soil Variables	Uncontaminated	Contaminated
pH (H_2O)	6.4000±0.1	5.6333±0.1
e^H(mv)	744.0000±9.4	646.0000±3.0
EC (dsm^{-1})	31.8333±1.7	64.4000±9.9
Organic C (gkg^{-1})	0.6233±0.0	2.7700±0.0
Total N (gkg^{-1})	0.16	0.28
Available P (gkg^{-1})	7.6067±0.4	5.0267±03
Ca^{2+} ($cmolkg^{-1}$)	6.6800±0.2	4.3733±0.2
Mg^{2+} ($cmolkg^{-1}$)	1.3767±0.0	0.3733±0.1
K^+ ($cmolkg^{-1}$)	0.1800±0.0	0.1367±0.0
Na^+ ($cmolkg^{-1}$)	0.3067±0.0	0.1800±0.0
CEC	9.0600±0.6	6.5333±0.4

ECEC ($cmolkg^{-1}$)	12.942±0.1	7.6000±0.1
Ex. Acidity ($cmolkg^{-1}$)	4.4000±0.0	2.5367±0.1
%BS	66.23	66.59%

Source: Project, 2022.

pH(H_2O) = Soil acidity in water; eH = Redox potential; EC = Electrical conductivity; CEC = Cation exchange capacity; ECEC = Effective cation exchange capacity; Ex. Acidity = Exchangeable acidity; %BS = Percentage base saturation

Table 4: Effects of crude oil contamination on soil chemical properties in Ughelli (Eruemukowarien)

Soil Variables	Uncontaminated	Contaminated
pH (H_2O)	6.400±0.0	5.5667±0.0
e^H (mv)	732.333±6.4	625.0000±22.5
EC (dsm^{-1})	31.4000±3.6	63.3333±7.9
Organic C (gkg^{-1})	0.6400±0.0	2.7933±0.0
Total N(gkg^{-1})	0.18	0.26
Available P(gkg^{-1})	7.5400±0.3	5.0400±0.3
Ca^{2+} ($cmolkg^{-1}$)	6.7167±0.3	4.3700±0.0
Mg^{2+} ($cmolkg^{-1}$)	1.3867±0.0	0.3967±0.1
K^+ ($cmolkg^{-1}$)	0.1800±0.0	0.1400±0.0
Na^+ ($cmolkg^{-1}$)	0.2800±0.0	0.1567±0.0
CEC	9.1067±0.6	6.6867±0.5
ECEC ($cmolkg^{-1}$)	13.0833±0.2	7.5667±0.1
Ex. Acidity ($cmolkg^{-1}$)	4.5067±0.1	2.5133±0.0
%BS	65.45	66.91

Source: Project, 2022.

pH(H_2O) = Soil acidity in water; eH = Redox potential; EC = Electrical conductivity; CEC = Cation exchange capacity; ECEC = Effective cation exchange capacity; Ex. Acidity = Exchangeable acidity; %BS = Percentage base saturation

Table 5: Effects of crude oil contamination on soil chemical properties in Warri (Iffie)

Soil Variables	Uncontaminated	Contaminated
pH (H_2O)	6.5667±0.0	5.700±0.0
e^H (mv)	744.000±8.9	644.6667±2.6
EC (dsm^{-1})	30.6333±1.1	62.4333±8.2
Organic C (gkg^{-1})	0.6733±0.0	2.8233±0.0
Total N(gkg^{-1})	0.16	0.29
Available P(gkg^{-1})	7.5400±0.3	5.2400±0.0
Ca^{2+} ($cmolkg^{-1}$)	6.7600±0.3	4.3800±0.1
Mg^{2+} ($cmolkg^{-1}$)	1.4133±0.0	0.3600±0.0
K^+ ($cmolkg^{-1}$)	0.1867±0.0	0.1400±0.0
Na^+ ($cmolkg^{-1}$)	0.2733±0.0	0.1467±0.0
CEC ($cmolkg^{-1}$)	9.2800±0.5	6.5367±0.4
ECEC ($cmolkg^{-1}$)	13.2467±0.2	7.5267±0.0
Ex. Acidity ($cmolkg^{-1}$)	4.6133±0.1	2.5000±0.1
%BS	65.17	66.78

Source: Project, 2022.

pH(H_2O) = Soil acidity in water; eH = Redox potential; EC = Electrical conductivity; CEC = Cation exchange capacity; ECEC = Effective cation exchange capacity; Ex. Acidity = Exchangeable acidity; %BS = Percentage base saturation

Table 6: Rating For Soil Fertility Classes in Nigeria

Parameter	Low	Medium
Organic C (gkg^{-1})	<10.0	10.0 - 15.0
Total N (gkg^{-1})	< 1.5	1.5 – 2.0
Available P ($mgkg^{-1}$)	< 8.0	8 – 20
Ca^{2+} ($cmolkg^{-1}$)	**< 5.0**	**5 – 10.0**
Mg^{2+} ($cmolkg^{-1}$)	**< 1.5**	**1.5– 3.0**
K^{+} ($cmolkg^{-1}$)	**< 0.2**	**0.2 – 0.40**
Na^{+} ($cmolkg^{-1}$)	**< 0.3**	**0.3 – 0.7**
CEC ($cmolkg^{-1}$)	**< 6 – 12**	**12.0 – 25.0**
%BS	**< 30 – 50**	**50.0 – 70.0**

Sources: FMA and NR (1990) Federal Ministry of Agriculture and Natural Resources

CONCLUSION

Crude oil contamination soils in this study, had adverse effect and significantly affected the chemical properties of the three studied areas in Delta State relative to uncontaminated soils. Findings of this study, indicated that crude oil contamination resulted to higher electrical conductivity (EC), Organic carbon and total nitrogen relative to every other properties examined. In respect to the above findings, the following conclusions were made by some amiable researchers that higher organic carbon in contaminated soil could be as a result of total petroleum hydrocarbon accumulated. Also, that higher total nitrogen in contaminated soils than uncontaminated soils could be attributed to the impact of crude oil in promoting organic carbon content of the soil including nitrogen dynamics and cycling in hydrocarbon contaminated soils and finally that increase in the EC might be attributed to the accumulation of exchangeable bases in the oil polluted soil which further affects the ionic stability of the soil. However, crude oil contaminated soils, generally affect chemical properties of soil which could also affect both physical and crop production of those areas experimented.

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