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A CASE STUDY OF THE EFFECTS OF OIL POLLUTION ON SOIL PROPERTIES AND GROWTH OF TREE CROPS IN CROSS RIVER STATE, NIGERIA

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Abstract: The effect of oil pollution on soil properties and growth of tree crop seedling was investigated for 20 weeks in a greenhouse experiment. Response of tree crop seedlings of cocoa, cashew, pawpaw and mango to pollution levels of 0, 100, 200, 400, 800 and 1000ml/20kg of soil was assessed at 6, 12 and 20 weeks after planting. Results obtained showed significant variation in physico-chemical properties of the soils. Organic carbon increased from 1.52 to 3.66%, nitrogen (0.12 – 0.32) total hydrocarbon (23.86 – 4684.0) in polluted soils. Available P(93.40 – 41.00), exchangeable Ca2+ (0.42-0.26), K+ and Na+ (0.19-0.05) and (0.14 – 0.04), ECEC and Cd also decreases with increase Cu, Mn and Pb with treatment concentration. Seedling germination and plant heights were significantly influenced at high pollution levels. However, these elements were still within the permissible range for agricultural soils. Farmers are advised not to cultivate oil polluted soils until remediation processes are carried out on the land. Liming, fertilization, enhanced ploughing and harrowing were recommended.

Keywords: Oil Pollution, Soil Properties, Tree Crops, Seedlings and Growth.

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INTRODUCTION

The oil industry is the main sustenance of Nigerian economy and at the same time a major source of land pollution in the Niger-Delta region of Nigeria. Oil pollution on land destroy soil fertility, hamper proper plant growth and destroy beneficial soil microbes. Ofomata (1997), Imevbore (1973) and Oguntoyimbo (1979) catalogued a number of oil spill contamination problems affecting some Nigerian towns. Most of the pollution cases involves accidental oil blowouts seepages and deliberate flushing activities which leaves a thick layer of crude oil over land, vegetation and water surfaces. The environmental effect of such blow-out is serious on soils and vegetation on which rural livelihoods depends. Cases of local oil pollution occur as a result of improper handling or mishaps such as burst pipes in places like Bonny, Okirika, Okwuzi, Obagu, Bori, Obirikom all in Rivers State, Nigeria (Ogbonna, 1981). Some of the farmers in these areas have been forced to give up their farmlands, this has serious implications on food production and livelihoods of the people.

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TABLE 1
Characteristics of Nigerian crude oil

Parameters	**Measured Values**
Specific gravity	0826
API gravity (A^0)	39.6
Bottom temperature (^0C)	101.0
Viscosity (CP)	0.29
Gas-Oil ratio	885
Reservoir depth (m)	2549
Carbon (%)	84.6
Hydrogen (%)	14.0
Sulphur (%)	0.75
Nitrogen (%)	0.86
Oxygen (%)	0.5
Trace metals (%)	0.03

Source: Modified after Asuquo, (1994).

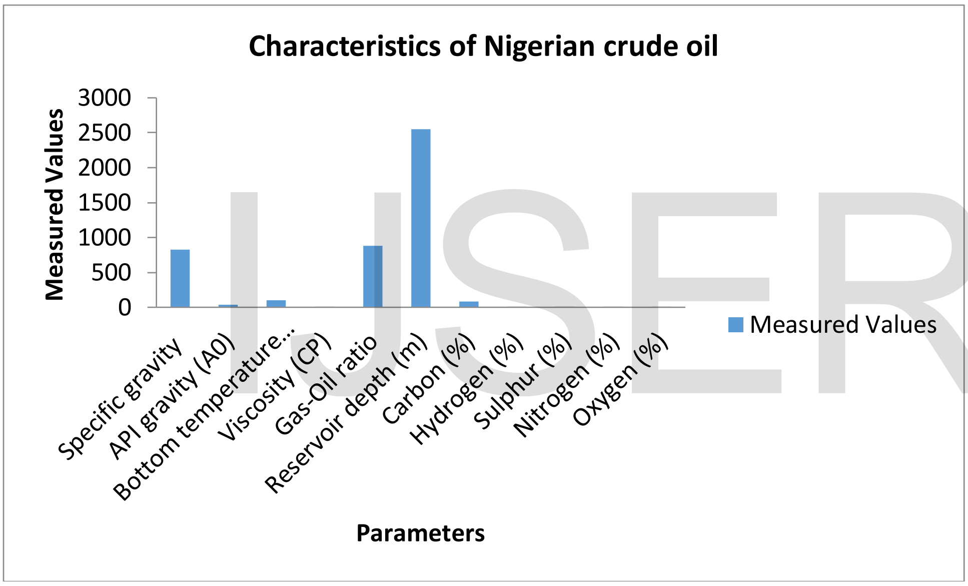

Fig. 1 : **Characteristics of Nigerian crude oil (Measured Values against Parameter)**

Crude oil and spent lubricating oil influence on soil properties ad growth of crops has been previously reported by Osuji*et al.*, (2004), Asuquo*et al.*, (2001), Adeniji*et al.*, (1983), Udo and Fayemi (1995), Amakiri and Onofeghara (1983). The presence of crude oil and spent lubricating oil in the soil adversely affected the physical, chemical and microbiological properties, these in-turn affects the germination of crop seeds and impede on the growth of cultivated crops (Baker, 1976; Dejong, 1980; Amadi*et al.*, 1993; Kayode*et al.*, 2009). The effect of crude oil and spend lubricating oil pollution on soil properties and growth of plant is dependent on their concentrations in a given soil. Beyond 3% concentration, these oils have been reported to be increasingly detrimental to the functional ability of the soil and plant growth (Ekundaya*et al*., 1989; Chukwu and Udoh, 2014). Other studies have reported inhibition of germination and growth of maize, okra and fluted pumpkin at higher doses. Soil organic matter increase and decrease in available phosphorus and exchange acidity. A marked increase in total hydrocarbon contents and levels of extractable heavy metals have been reported by Alloway and Ayres, (1997), Ebong*et al*., (2007) and Kayode*et al*., (2009) with an increase in treatment concentration. They also opined that soil pollution with crude oil and spent lubricating oil destroys soil structure, increased bulk density, soil porosity reduction in soil capillary, aeration and nutrients availability and uptake by plants.

Data on crude oil and spent lubricating oil pollution on tree crops and its post-spill management area still very scanty and inadequate in Cross River State. Studies in Economic tree crops have not been carried out in Cross River State. This study will help to provide baseline data to assist in determining future severity of the effects. Hence the aim of this study is to examine the effects of crude oil and spent lubricating oil on soil physico-chemical properties, germination and growth of tree crops such as coca, cashew, pawpaw, and mango.

MATERIALS AND METHODS

Study Area Location: Field experiments were conducted at Demonstration Farm of the University of Calabar. It lies essentially between Latitude $4^0 54'$N and longitude $8^0 51'$E. the area has a humid tropic climate with annual rainfall between 2,000mm with a little marked dry season. Daily temperatures vary between 26^0C to 31^0C with a high relative humidity of 80 to 98% (Eshett, 1987).

Seeds of cocoa (*Theobroma cocoa*) and Mango (*Mangifera indica*) were collected from Cross River Agricultural Development Project (CRADP) Calabar. The seeds were tested for viability by soaking in deionized water for four hours. Soil samples was collected from the Demonstration Farm into 180 polyethene bags contain 20kg of top soil, each bag measuring 40 by 35cm with perforations at the sides and bottom (see Table 2).

TABLE 2
Chemical properties of soils used for the experiments

Measured parameters	Control	100 ml/20kg	200 ml/20kg	400 ml/20kg	800 ml/20kg	1000 ml/20kg	Critical Values
pH	5.64	5.76	5.79	5.82	5.85	5.87	6.00
e^H (mv)	750	545	556	583	602	630	689
Temp. (^{0}C)	26.5	1.54	2.68	3.22	3.54	3.66	2.0

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EC (ds/cm)	0.082	0.042	0.046	0.050	0.052	0.054	0.055
TOC (%)	1.52	1.54	2.68	3.22	3.54	3.66	2.0
TN (%)	0.12	0.18	0.21	0.27	0.30	0.32	0.2
Available P ($mgkg^{-1}$)	93.40	58.9	53.60	51.80	48.40	41.0	20-100
Exchangeable Ca^{2+}($mgkg^{-1}$)	0.42	0.40	0.37	0.34	0.31	0.26	10
Exchangeable K^{+} ($mgkg^{-1}$)	0.19	0.16	0.13	0.11	0.09	0.05	0.2-0.3
Exchangeable Ma^{+} ($mgkg^{-1}$)	0.14	0.11	0.09	0.08	0.06	0.04	0.05
Exchangeable Mg^{+} ($mgkg^{-1}$)	1.22	1.00	0.8	0.6	0.4	0.2	4-8.0
Exchangeable Acidity ($mgkg^{-1}$)	5.0	2.4	2.6	2.8	3.0	3.4	0.7-5.0
ECEC	7.20	3.85	5.56	3.45	3.24	3.08	3-20
Base Salt (%)	70.6	67.80	65.4	60.2	58.0	47.6	50-70
Sand (%)	82.0	79.40	79.20	79.0	78.70	78.20	-
Silt (%)	11.2	14.00	14.60	14.80	15.20	15.90	-
Clay (%)	6.80	6.60	6.20	6.00	5.80	5.50	-

The experiment was carried out in two stages. Stage 1 was to test for the effect of crude oil and spent lubricating oil on the germination of coca, cashew, pawpaw and mango seeds. Treatment levels of 0, 100, 200, 400, 800 and 1000ml/kg soil were used. The soil samples were polluted 1 week before planting and percentage germination was measured 6 weeks after planting. In stage 2, same treatments as in stage 1 were used but the crude oil and spent lubricating oil was applied 6 weeks after planting of seeds. At each stage, soil physico-chemical properties were tested and percentage germination and plant growth height were recorded and presented in Tables 3 and 4.

TABLE 3
Effect of crude oil and spent lubricating oil contamination levels on seed germination percentage

Level of oil contamination (ml/20kg soil)	Cocoa	Cashew	Pawpaw	Mango
0	98	100	96	99
100	92	95	94	97
200	70	77	81	72
400	51	42	59	37
800	34	36	43	29
1000	5	20	34	16

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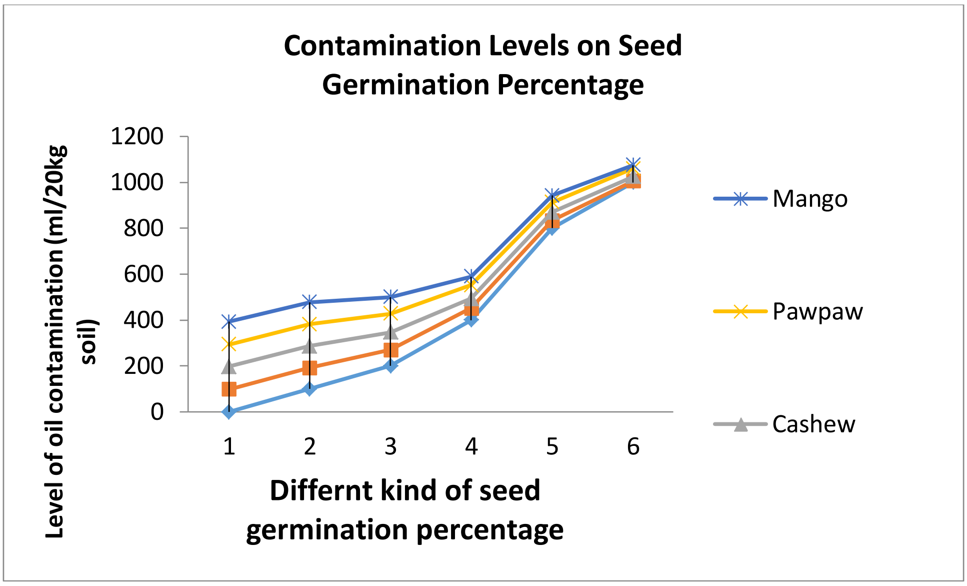

Fig. 2: Effect of crude oil and spent lubricating oil contamination levels on seed germination percentage

TABLE 4
Effect of crude oil and spent lubricating oil contamination levels on seedlings height

Level of oil contamination (ml/20kg soil)	Cocoa			Cashew			Pawpaw			Mango		
	6wks	12wks	20wks	6wks	12wks	20wks	6wks	12wks	20wks	6wks	12wks	20wks
0	24.0	33.4	42.7	18.0	35.0	45.2	17.4	28.9	35.4	16.9	28.6	41.8
100	17.4	29.5	37.2	14.2	29.6	40.0	14.9	23.2	29.6	15.2	25.0	37.2
200	14.8	24.6	31.5	12.0	25.0	34.4	12.2	16.4	25.4	13.0	19.8	29.1
400	12.2	19.8	28.0	9.8	21.4	29.5	10.6	12.0	18.2	11.6	17.4	23.7
800	8.9	14.6	19.4	7.2	17.8	20.9	8.2	10.1	15.9	8.4	15.0	19.9
1000	5.7	7.2	12.8	5.9	12.4	14.2	5.6	8.3	13.0	6.9	12.0	14.2

LABORATORY ANALYSIS

Soil pH, *e*H, temperature (^{O}C), conductivity (µsdm^{-3}) were measured insitu using portable pH/eH meter (WTW 90), conductivity-temperature meter (Hach instrument) in soil/water. Particle size analysis was done using the hydrometer method (Bouyoucous, 1951) available phosphorus (Bray and Kurtz, 1945), total nitrogen (micro-Kjedahl method), exchangeable bases were displaced from 5g of soil using neutral normal ammonium acetate as the extracting solution. Calcium and magnesium were determined by EDTA titration method, sodium and potassium were determined through flame photometer (Jackson, 1962), exchangeable acidity determined by KCl extraction method (Maclean, 1965), effective cation exchange capacity (ECEC) through summation of exchange of exchangeable acidity ad bases (soil survey staff, 2006). Base saturation was estimated as a sum of exchangeable basic cations dividend by ECEC and expressed in percentage. Total hydrocarbon was extracted with 20ml of Xylene and measured using spectrophotometer as described by Udo *et al*., (2009), Usuji and Nwoye (2007).

RESULTS AND DISCUSSION

(a) Germination

Seed sprouting began 10 days after planting in the control and 16 days after planting in the polluted samples. The percentage germination for each treatment was determined and presented in Table 3. Results revealed that the unpolluted soil was higher than soil samples treated with crude oil and spent lubricating oil. The effect increased as concentration of treatment increases. There was little variation in the means and coefficient of variation among crude oil and spent lubricating oil treated samples. The reduced germination is adduced to the fact that volatile fractions of oil could enter the seed coat and induce unfavourable conditions for seeds germination. Also soils polluted with crude oil and spent lubricating oil show poor wettability, reduced aeration and compaction and increased propensity to heavy metal accumulation. These observation is in tandem with Udo and Fayemi (1995), Kayode *et al*., (2009), Osuji and Nwonye (2007).

(b) Crop growth height

Crop seedlings height were monitored and taken 6 weeks after planting, 12 weeks after planting and 20 weeks after planting for stage 1 and 2 experiments. Normal luxuriant growth occurred at the control and the first 5 weeks of planting in the stage 2 experiment with some of the plants attaining a height of 48-66cm at the end of 6 weeks, while in the polluted soils plant growth was a function of the degree of pollution in each treatment level. Plant recorded an average height of 38 to 44cm for treatment levels not greater than 400ml/20kg and the least was 800 to 1000 ml/kg (see Table 4). Statistical difference exists among the treatment levels. This findings is in agreement with Udo and Fayemi (1975), Toogood and Rowell (1997), Odu (1978), Amakin and Onofegha (1983) and Asuquo*et al*., (2000), who maintained that seedling growth rate is a function of the treatment concentration. The differential growth retardation may be due to impaired transpiration and photosynthesis, poor aeration and root penetration (Fig. 1 & 2).

(c) Soil physico-chemical properties

Results on mechanical analysis of soil as presented in table 2 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. The redox potential decreased markedly in lower treatment concentrations. However, the recorded redox potential values are all well-oxidized soils except for treatment concentrations of 1000ml/20kg. Brady and Weil (1996), Oguntoyinbol (1999) Kayode*et al*., (2009), Asuquo *et al*., (2001) have reported that the presence of some sulphur and vanadium compounds often present in trace amounts in crude oil could increase the rate of chemical oxidation and redox potential values of oil contaminated soil. Results of chemical properties are presented in Table 2.

Findings show a gradual increase in soil pH and electrical conductivity 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 crop plants. Nitrogen and 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 is also because microorganisms have adapted to soil conditions and are now able to utilize the carbon content of the soil for their metabolism. Available phosphorus content decreased from 93.40mg/kg in the control to 50.24mg/kg^{-1} in treatment concentration of 800ml/20kg and further decreased to 41.0mg/kg^{-1} as the treatment concentration increased. In like ways, exchangeable K^+, Na^+ and Mg^+ decreased with increased treatment concentrations for all the crops. This is in tandem with Ekundaye *et al*., (1989), Adefemi and Awokunmi, (2009). The plausible reasons for these decreasing trend may 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; Kayode *et al*., 2009; Brady and Weild, 1996). Exchangeable cations (Ca_2^+, K^+, Mg^+, Na^+) were susceptible to reduction in the oil polluted soils. The critical values of Ca^{2+} and K^+ from control and polluted soils were far below agricultural productivity (10Cmolkg^{-1} soil and 0.2 to 0.3 Cmolkg^{-1} soil). Effective cation exchange capacity ECEC) shows a general decreasing trend with increase in treatment concentrations compared to unpolluted soils (see Table 5).

TABLE 5

Total extractable heavy metals in crops and soils after the experiment

Treatment levels/ heavy metals concentration	0ml/20kg		100ml/20kg		200ml/20kg		400ml/20kg		800ml/20kg		1000ml/20kg	
	Soil	**Crop**	**Soil**	**Crop**	**Soil**	**Crop**	**Soil**	**Crop**	**Soil**	**Crop**	**Soil**	**Crop**
Fe ($mgkg^{-1}$)	54.6	46.0	59.0	52.1	65.4	60.5	72.1	68.3	80.5	73.9	132.4	121.8
Zn ($mgkg^{-1}$)	2.20	1.85	2.60	2.04	2.80	2.50	3.04	2.80	3.86	3.30	4.10	3.60
Cu ($mgkg^{-1}$)	4.25	3.60	4.82	4.10	5.14	4.30	5.50	4.70	5.80	4.92	6.84	5.20
Mn ($mgkg^{-1}$)	18.90	15.00	20.0	17.20	22.30	19.10	25.40	20.8	27.20	22.4	29.80	25.3
Ni ($mgkg^{-1}$)	3.20	2.80	2.50	2.10	2.20	1.82	2.02	1.64	1.82	1.57	1.50	1.34
Cd	2.40	2.02	2.18	1.94	2.10	1.86	0.72	0.16	0.51	0.44	0.28	0.12
Pb	0.67	0.56	0.72	0.65	0.88	0.73	0.94	0.81	1.22	0.89	1.38	1.14
V ($mgkg^{-1}$)	0.52	0.47	0.64	0.50	0.71	0.59	0.85	0.63	0.92	0.70	1.02	0.82

Levels of extractable heavy metals (Mn, Cu, Ph, Ni, Cd, V and Zn) concentration in crop samples based on Weilding and Dress (1983) rating after experiment portrays that Mn, Fe, Zn, Cu and Cd were highly variable. The coefficient of variability amongst crops was relatively significant at 0.5% except for pawpaw that show a wide variability. 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 they did not exceed the permissible range for agricultural soils which is 10-30mg/kg^{-1} for Pb and 20-90mg/kg^{-1} for Mn. Cadmium (Cd) content was generally low whereas 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 Alloway (1995), Ademoroti (1996), Fatoki and Ayodele (1996), Chamey and Giordano (1977) 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 bioavailable as they are absorbed by plants and are further recycled (Murray, 1996; Shreck, 1998).

The hydrocarbon contents of the soils and crops after the experiment are presented in Table 6. The results shows that total hydrocarbon content (THC) of the soils and cops increases with an increase in treatment concentration in all the crops. The higher THC observed in pawpaw than other crops indicates that pawpaw absorbed more THC than cocoa, cashew and mango. At higher treatment concentration greater than 400ml/20kg soil, germination, rooting, leaves and stem development was impeded, cocoa, cashew and mango showed symptoms of vein clearing and chlorosis at the 8th week after planting and wilting was noticed at the 10th week after planting, while some of the crops wilted permanently after the 11th week after planting and the 12th week due to chronic toxicity. The results confirm the importance of pawpaw in the bioremediation of soils polluted by crude oil and spent lubricating oil during clean-up operations.

TABLE 6
Total Hydrocarbon (THC) content of polluted soils and crops

Crops/Treatment	Levels (ml/20kg soil)	THC levels of soils	THC levels of crops
Cocoa	0ml	23.86	17.24
	100ml	2018.00	83.48
	200ml	2554.00	165.72
	400ml	3241.00	386.00
	800ml	3854.24	728.64
	1000ml	4391.86	1034.20
Cashew	0ml	23.86	19.84
	100ml	1893.44	77.92
	200ml	2425.00	328.60
	400ml	3214.00	413.16
	800ml	3864.92	681.08
	1000ml	4277.00	924.86
Pawpaw	0ml	23.86	20.62
	100ml	1324.20	108.74
	200ml	3241.40	301.08
	400ml	4148.42	462.46
	800ml	4466.60	581.94
	1000ml	4684.00	788.12
Mango	0ml	23.86	18.60
	100ml	1658.20	168.66
	200ml	2499.64	387.40
	400ml	3736.90	463.84
	800ml	4189.40	492.00
	1000ml	4422.00	58480

CONCLUSION

The agricultural use and management of soil is largely dependent on the characteristics and qualities of the soil. Results from the study revealed that 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^+, Ca^{2+} and ECEC decreases with increase in treatment concentration. Heavy metals in the soil were highly variable as Fe, Mn, Pb contents were increased as treatment concentration increases. Oil pollution had a depressing effect on Cd. To minimize this problem, liming, fertilization, enhanced ploughing and harrowing are recommended. Farmers are advised not to cultivate an oil polluted soils until remediation processes are carried out on the land.

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