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# Effect of Oil Pollution on Soil Properties and Performance of Maize *(Zea Mays)* Grown on Soil Derived from Coastal Plain Sand in Obio Akpa, Akwa Ibom State

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**ABSTRACT:** The study was conducted to determine the impact of oil pollution on the soil qualities and performance of maize (*zea mays*) cultivated on sand from the coastal plain in Obio Akpa, Akwa Ibom State. The investigation was conducted out at Akwa Ibom State University's teaching and research farm. Soil samples were obtained from a depth of 0 to 30 cm. Ten (10) kg of soil samples were weighed into 45 experimental pots with a capacity of 12 litres each. The pots were laid out in 3 x 5 split plot arrangement fitted into randomized complete block design (RCBD) with three replications. The main plots were the three treatment sources (kerosene, engine oil and crude oil) and the subplots were the five rates of treatment (0ml, 40ml, 60ml, 80ml and 100ml). The treatments were applied two weeks before planting. Plant emergence (germination rate) after two weeks, plant height, leaves length, number of leaves, stem girth, fresh weight and dry weight were measured. The results showed that pots contaminated with crude oil and engine oil were significantly higher ($p < 0.05$) in sand fraction and lower ($p < 0.05$) in clay fraction after the experiment than before the experiment. Kerosene raised the soil pH from 4.4 to 4.8; crude oil raised the soil pH from 4.4 to 4.6 while engine oil raised the pH from 4.4 to 4.7. Mean organic C of plots contaminated with kerosene and crude oil were significantly higher ($p < 0.05$) after the experiment than before the experiment. The trend was Kerosene > crude oil > engine oil. The mean available P before the experiment was significantly higher ($p < 0.05$) than that of plots contaminated with kerosene, crude oil and engine oil. after the experiment. Kerosene, crude oil and engine oil contamination raised exchangeable Ca and exchangeable Na content of the soil and reduced exchangeable Mg, K, potential acidity, ECEC and base saturation. Germination rate, number of leaves, plant height, leave length, stem girth, fresh weight and dry weight decreased with increasing contamination rate. The trend was 0 ml > 40 ml > 60 ml > 80ml > 100ml. Further investigation should be carried out to identify plant that can tolerate crude oil pollution and remediation should be carried out to regain the originality of the soil.

**Keywords:** Oil pollution, coastal plain sand, soil properties, maize plant, and growth and yield parameter

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## INTRODUCTION

Oil industry is the main sustenance of Nigeria economy and at the same time a major source of land pollution in Niger-Delta region of Nigeria. Oil spillage on land destroys soil fertility, hamper proper plant growth and destroy beneficial soil microbes. Ofomata, (1997) and Umoh *et al* (2017) give a number of spill contamination problems which affect Agricultural land and these can quickly spread through leaching and runoff due to high rainfall in the zone (Umoh *et al.*, 2018; Sunday *et al.*, 2020) and most of the pollutions cases involves accidental, oil blowouts seepages and deliberate flushing activities which leave a thick layer crude oil and it's product over land, vegetation and water surfaces, The environmental effect of such blowout is serious on soil and vegetation on which rural livelihoods depends. Cases of local oil pollutions occur as a result of improper handling or mishap such as burst pipes in places like Bonny, Okirika, Bori Obirikom,Obagu, in River State and also in Mbo, Eastern obolo in Akwa Ibom state all in Nigeria (Ogbonna, 1981) some of the farmers in these areas have been force to give up their farmlands, this has serious implications on food production and livelihoods of the people.

Based on previous research, it has been established that crude oil can have a significant influence on soil properties and the growth of crops. This finding has been supported by studies conducted by Ijah and Iren (2019), Osuji et al. (2004), and Asuquo et al. (2001). The impact of crude oil on soil properties and crop growth is an important area of study with implications for agricultural productivity and environmental sustainability. Further research in this area is warranted to better understand the mechanisms through which crude oil affects soil and crops, as well as to develop potential mitigation strategies. The presence of crude oil in the soil adversely affect the physical, chemical and microbiological properties of the soil, these in-turn affect the germination of crop, seeds and impede on the growth of cultivated crops. The effect of crude oil pollutions on soil properties and growth of crops is dependent on their concentration in a given soil. These oils have been reported to be increasingly detrimental to the functional ability of the soil and plant growth (Chukwu and Udoh 2014, Ekundaya *et al*., 1989). Several studies have been reported inhibitions 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 has been reported by Kayode *et al*., (2009) they also opined that soil pollution with crude oil destroys soil structure, increased bulk density, soil porosity, reduction in soil capillary, aeration and nutrients availability and uptake by plants. A study carryout by Chukwu and Udoh, 2014 showed that crude oil spillage on soil, delayed germination and reduced nutrients uptake of maize.

Kerosene is thin oil distilled from petroleum or shale oil, used as a fuel or alcohol denaturant. Thus, due to its relative availability, affordability and application over a vast majority of processes and machinery, spillage or seepage of this product occurs though not frequently in large quantities at a given time but consistently over a period of time and ~~to~~ accumulate and result in chronic contamination in the soils. The effect of these chemicals on indigenous microbiota disrupts the biogeochemical cycling of elements and condemned engine oil on soil reduced growth, chlorophyll and protein levels of Amaranthus hybridus.

Maize (Zea Mays) also referred to as corn is a cereal plant of the family poeceae, that today constitutes the most widely distributed food plant in the world Ekwere *et al.,* 2013). Zea is an ancient Greek word which means "sustaining life", and Mays is a life word from Taino language meaning "life giver". The word "Maize" is from Spanish connotation "maize" which is the best way of describing the plant. Maize has become a staple food in many parts of the world, with the total production of maize surpassing that of wheat or rice. However, maize is consumed directly by humans, mostly used for ethanol, animal feed and other maize products such as corn starch and corn syrup (Foley and Jonathan, 2019; Ekwere *et al.,* 2009). The following researchers; (Umoh *et al.,* 2020, Umoh *et al.,* 2021; Udoh 2017) reported that maize required a well drain and a fertile soil with pH range of 5-6 for optimal yield in soils of Eastern Nigeria. The aim of this research is to investigate the effect of oil pollution on soil properties and growth response of maize (Zea Mays) in oil polluted soils.

## MATERIALS AND METHOD

### Experimental site

The study was conducted in the Screen House, Faculty of Agriculture, Akwa Ibom State University, which lies between Latitudes $4^{0}32^{!}$ N and $5^{0}33^{!}$ N and Longitudes $7^{0}25^{!}$ E and $8^{0}25^{!}$ E, with a mean annual rainfall of over 300mm and temperature varies between 26 and $28^{0}$C.

### Soil sampling and laboratory analysis

A composite soil sample on coastal plain sand at 0-15cm depth was collected for laboratory analysis and also used for the Pot experiments. The samples were air-dried and sieved through 2mm mesh and used for the analysis.

### Laboratory analyses

The following soil parameters as described by Udo *et al*., (2009) were determined. Particle size distribution was determined by the Bouyoucos hydrometer method using sodium hexameta-phosphate as dispersing agent. The soil pH was measured in soil to water ratio of 1:2.5 using a glass electrode pH meter. The electrical conductivity was measured in the extract from 1:2.5 soils: water suspension using a conductivity bridge. Soil organic carbon was determined by wet oxidation method and the value was multiplied by a factor of 1.72 to obtain organic matter. The nitrogen in the soil was determined by micro Kjeldahl distillation method. Available Phosphorous in the soil was determined by Murphy and Relay method after extraction by Bray p-1 extractant. The exchangeable cations in the soil were extracted using IN $NH_4OAC$ (pH 7.0). K and Na in the extracts were measured using flame photometry while Mg and Ca were determined by atomic absorption spectrophotometry. Effective Cation Exchange Capacity (ECEC) was obtained by the summation of the exchangeable cation and exchangeable acidity was extracted with KCl and determined by titration with

0.05M NaOH using phenolphthalein indicator.

Base Saturation (%) was calculated using the formula:

$\frac{TEB}{ECEC} X \frac{100}{1}$ where TEB = total exchangeable bases and ECEC = effective cation exchange capacity

## Pot experiment

Ten (10) kilograms of the soil samples was weighed into the 45 pots with 12 liters capacity. The experimental design was 3×5 split plot arrangement fitted into a randomized complete block design with three replications. The main plots were three treatment sources (Crude oil, Kerosene, and condemned engine oil) and the sub-plots was four rates of treatment (0ml, 40ml, 60ml, 80ml and 100ml) and the treatments was applied two weeks before planting. A total of 45 samples (pots) were generated. Ten seeds of Hybrid maize (oba super 2) was sown per pot and irrigated at four days interval until harvest. The following growth parameters were assessed. Plant emergence after two weeks, was done by counting the germinating plants per pot, plant height was measured using a meter rule, leaf area was obtained by measuring the length of the longest leaves, stem girth was determined by using a string tied around the plant and the length of the string read from a meter rule, Number of leaves was determined by counting the full opened leaves per plant. The fresh weight and dry matter yield was determined at the end of the experiment by carefully uprooting all the survived plant in the pot, rinse the soil and weigh, they were also oven dried and weighed using electronic weighing balance (Oyedeji *et al.,* 2013).

## Statistical analysis

Data collected were subjected to analysis of variance (ANOVA). The treatment means were separated for the significant difference using the least significant difference at a 5% probability level.

## Physiochemical properties of soil before and after the experiment

The physicochemical properties of soil of the study area before and after the experiment are presented in Table1. Before the experiment, sand fraction ranged from 95.00 to 96.30 % with a mean of 95.17 %. Silt fraction ranged from 1.80 to 1.85 % with a mean of 1.82 %. The clay fraction ranged from 3.00 to 3.02 % with a mean of 3.01 %. Soil texture was sand. After the experiment, the sand fraction of pot contaminated with kerosene ranged from 94.60 to 95.50 % with a mean of 94.97 %; silt ranged from 2.20 to 2.80 % with a mean of 2.47 % and clay ranged from 3.00 to 3.00 % with a mean of 3.00 %. Soil texture was sand. The sand fraction of pot contaminated with crude oil ranged from 96.20 to 96.20 % with a mean of 96.20 %; silt ranged from 1.80 to 1.80 % with a mean of 1.80 % and clay ranged from 2.00 to 2.00 % with a mean of 2.00 %. Soil texture was sand. The sand fraction of pot contaminated with engine oil ranged from 96.20 to 96.20 % with a mean of 96.20 %; silt ranged from 1.60 to 1.60 % with a mean of 1.60 % and clay ranged from 2.00 to 2.20 % with a mean of 2.130 %. Soil texture was sand.

Although, there was no variation in textural class before and after the experiment, but sand fraction of pots contaminated with crude oil and engine the sentence is incomplete oil were after the experiment than before the experiment. Similarly, clay fraction of pots contaminated with crude oil and engine oil were significantly lower ($p < 0.05$) after the experiment than before the experiment. The variation could be attributed to crude oil and engine oil causing aggregation of soil particles and flocculation of aggregates resulting in more macropores, which brings about down ward movement of suspended clay (illuviation), leading to more sand and less clay in the surface soil (Kayode *et al.*, 2009).Before the experiment, soil pH was 4.4. After the experiment, soil pH of pot contaminated with kerosene was 4. 8. Soil pH of pot contaminated with crude oil was 4.6 while soil pH of pot contaminated with engine oil was 4.7. Kerosene raised the soil pH from 4.4 to 4.8; crude oil raised the soil pH from 4.4 to 4.6 while engine oil raised the pH from 4.4 to 4.7. The trend was kerosene > engine oil > crude oil. Soil pH of all the contaminated pots was significantly higher ($p < 0.05$) than before the experiment. Generally, the soil pH was low in both polluted and unpolluted soils and contradict the work of Wang *et al*, 2009) who reported increased in soil pH in crude oil polluted soil. The relatively lower soil pH could be attributed to the acidic nature of the oil (Ijah *et al.*, 2018) and the presence of hydrocarbon that produces organic acids when acted upon by microorganisms Osuji, L.C. and Nwoye, L. (2007). Before the experiment, electrical conductivity was 0.07 $dSm^{-1}$. After the experiment, electrical conductivity of contaminated with kerosene was 0.08 $dSm^{-1}$. Electrical conductivity of pot contaminated with crude oil was 0.08 $dSm^{-1}$ while that of pot contaminated with engine oil was also 0.08 $dSm^{-1}$. Electrical conductivity of pots contaminated with kerosene; crude oil and engine oil was significantly higher than before the experiment. This increase could be attributed to hydrophobic nature of kerosene; crude oil and engine oil that induce a potential drought in the soil that aggravate salinity. Before the experiment, organic C varied from 2.28 to 2.29 % with a mean of 2.3 %.

**Table 1**: Physicochemical properties of the soil before and after experiment

| **Oil spillage** | **Sand (%)** | **Silt (%)** | **Clay (%)** | **PH** | **EC ($dSm^{-1}$)** | **Org. C (%)** | TN (%) | AvP (mg/kg) | Extract of ions | | | | Exh, Acidity cmol/kg | ECEC cmol/kg | BS (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Before** | | | | | | | | | **Exh.Ca Cmol/kg** | **Exh. Mg Cmol/kg** | **Exch K Cmol/kg** | **Exch.Na Cmol/kg** | | | |
| Minimum | 95.00 | 1.80 | 3.00 | 4.4 | 0.07 | 2.28 | 0.14 | 10.10 | 1.32 | 2.01 | 1.30 | 0.06 | 1.93 | 6.63 | 70.9 |
| Maximum | 96.30 | 1.85 | 3.02 | 4.4 | 0.07 | 2.29 | 0.14 | 10.20 | 1.33 | 2.02 | 1.30 | 0.06 | 1.93 | 6.63 | 70.9 |
| Mean | 95.17a | 1.82a | 3.01c | 4.4a | 0.07a | 2.28a | 0.14ab | 10.17d | 1.32a | 2.02c | 1.30c | 0.06a | 1.93bc | 6.63c | 70.9a |
| Kerosene | | | | | | | | | | | | | | | |
| Minimum | 94.60 | 2.20 | 3.00 | 4.8 | 0.08 | 2.84 | 0.02 | 8.03 | 1.40 | 0.94 | 0.03 | 0.07 | 1.83 | 5.38 | 64.7 |
| Maximum | 95.50 | 2.80 | 3.00 | 4.8 | 0.08 | 3.03 | 0.20 | 8.07 | 1.44 | 1.04 | 1.24 | 0.07 | 1.94 | 5.69 | 66.9 |
| Mean | 94.97a | 2.47b | 3.00c | 4.8d | 0.08b | 2.90b | 0.13a | 8.06a | 1.43bc | 0.97b | 1.16bc | 0.07b | 1.89ab | 5.53b | 65.8b |
| Crude oil | | | | | | | | | | | | | | | |
| Minimum | 96.20 | 1.80 | 2.00 | 4.6 | 0.08 | 3.54 | 0.20 | 9.0 | 1.38 | 0.92 | 0.94 | 0.08 | 1.94 | 5.36 | 62.7 |
| Maximum | 96.20 | 1.80 | 2.00 | 4.6 | 0.08 | 3.62 | 0.29 | 9.07 | 1.46 | 1.16 | 1.00 | 0.08 | 2.00 | 5.68 | 65.1 |
| Mean | 96.20b | 1.80a | 2.00a | 4.6b | 0.08b | 3.57c | 0.25b | 9.03b | 1.43c | 1.01b | 0.97a | 0.08c | 1.97c | 5.47ab | 63.9b |
| Engine oil | | | | | | | | | | | | | | | |
| Minimum | 96.20 | 1.60 | 2.00 | 4.6 | 0.07 | 2.20 | 0.18 | 9.05 | 1.3 | 0.84 | 0.98 | 0.07 | 1.84 | 5.13 | 64.1 |
| Maximum | 96.20 | 1.80 | 2,20 | 4.7 | 0.08 | 2.32 | 0.25 | 9.50 | 1.4 | 0.84 | 1.21 | 0.07 | 1.84 | 5.31 | 67.4 |
| Mean | 96.20b | 1.67a | 2.13b | 4.67c | 0.08b | 2.28a | 0.23ab | 9.20c | 1.4ab | 0.84a | 1.12ab | 0.07b | 1.84a | 5.23a | 65.5b |

Minimum is the control, maximum is the contamination rate

After the experiment, Organic C of pot contaminated with crude oil varied from 3.54 to 3 3.62 % with a mean of 3.6 while organic C of plot contaminated with engine oil varied from 2.20 to 2.32 % with a mean of 2.3 %. Mean organic C of pots contaminated with kerosene and crude oil were significantly higher ($p < 0.05$) than before the experiment and that of pot contaminated with engine oil. The trend was Kerosene > crude oil > engine oil. The increase in mean soil organic carbon in pots contaminated with kerosene and crude oil could be attributed to the higher amount of hydrocarbon content in kerosene and crude oil (Osuji et al., 2004). Similarly, Ijah *et al.* (2008) and Ijah *et al.* (2018) also reported increase in organic carbon content in crude oil polluted soil and attributed it to microbial mineralization of crude oil in the soil. Before the experiment, total N was 0.14 %. After the experiment, total N of pot contaminated with kerosene varied from 0.02 to 0.2 % with a mean of 0.13%. Total N of pot contaminated with crude oil varied from 0.2 to 0.29 % with a mean of 0.25 while total N of pot contaminated with engine oil varied from 0.18 to 0.25% with a mean of 0.23 %. The mean total N of pots contaminated with crude oil and engine oil were higher after the experiment than before the experiment and that of pot contaminated with kerosene although not statistically significant ($p < 0.05$). kerosene varied from 2.84 to 3.03 % with a mean of 2.9 Total N was moderately low before the experiment and moderately high in pots contaminated with crude oil and engine oil after the experiment. The increase in total N could be attributed to the total hydrocarbon content which in turn give rise to organic matter, which later under mineralization to release N (Osuji et al., 2004). Before the experiment, available P varied from 10.10 to 10.20 mg/kg with a mean of 10.17 mg/kg. After the experiment, available P of pot contaminated with kerosene varied from 8.03 to 8.07 mg/kg with a mean of 8.06 mg/kg Available P of pot contaminated with crude oil varied from 9.0 to 9.07 mg/kg with a mean of 9.03 mg/kg while available P of pot contaminated with engine oil varied from 9.05to 9.50 mg/kg with a mean of 9.20 mg/kg. The mean available P before the experiment was significantly higher ($p < 0.05$) than that of pots contaminated with kerosene, crude oil and engine oil after the experiment. Generally, available P was moderate in all the pots before and after the experiment. The trend in available P reduction was kerosene < crude oil < engine oil. The reduction in available P after the experiment could be attributed to P fixation in polluted soils (Ijah *et al,* 2008) and microbes that utilize TPH as carbon source, when they degrade hydrocarbon (Wang *et al*., 2009). Before the experiment, exchangeable Ca varied from 1.32 to 1.33 cmol/kg with a mean of 1.32 cmol/kg. After the experiment, exchangeable Ca of pot contaminated with kerosene varied from 1.40 to 1.44 cmol/kg with a mean of 1.43 cmol/kg

Exchangeable Ca of pot contaminated with crude oil varied from 1.38 to 1.46 cmol/kg with a mean of 1.43 cmol/kg while exchangeable Ca of pot contaminated with engine oil varied from 1.30 to 1.40 cmol/kg with a mean of 1.4 0 cmol/kg. Mean exchangeable Ca before the experiment was significantly lower ($p < 0.05$) than that of pots contaminated with kerosene and crude oil but not different from that of engine oil after the experiment. Kerosene, crude oil and engine oil contamination raised exchangeable Ca content of the soil.

However, exchangeable Ca was very low before and after the experiment. The increase in exchangeable Ca could be attributed to the association of oil pollution with accumulation of exchangeable bases and reduction of exchangeable acidity (Osuji et al., 2004). Before the experiment, exchangeable Mg varied from 2.01 to 2.02 cmol/kg with a mean of 2.02 cmol/kg. After the experiment, exchangeable Mg of pot contaminated with kerosene varied from 0.94 to 1.04 cmol/kg with a mean of 0.97 cmol/kg Exchangeable Mg of pot contaminated with crude oil varied from 0.92 to 1.16 cmol/kg with a mean of 1.01 cmol/kg while exchangeable Mg of pot contaminated with engine oil was 0.84 cmol/kg. Mean exchangeable Mg before the experiment was significantly higher ($p < 0.05$) than that of pots contaminated with kerosene, engine oil and crude oil after the experiment. Mean exchangeable Mg was moderate before the experiment and varied from low to moderate after the experiment. The reduction in exchangeable Mg could be attributed to microbes that utilize TPH as carbon source, may also utilize exchangeable Mg when they degrade hydrocarbon (Wang *et al*., 2009). Before the experiment, exchangeable Na was 0.06 cmol/kg. After the experiment, exchangeable Na of pot contaminated with kerosene was 0.07 cmol/kg. Exchangeable Na of pot contaminated with crude oil was 0.008 cmol/kg while exchangeable Na of pot contaminated with engine oil was 0.07 cmol/kg. Mean exchangeable Na before the experiment was significantly lower ($p < 0.05$) than that of pots contaminated with kerosene, engine oil and crude oil. Mean exchangeable Na was very low before and after the experiment. The increase in exchangeable Na could be attributed to the association of oil pollution with accumulation of exchangeable bases and reduction of exchangeable acidity (Osuji et al., 2004). Before the experiment, exchangeable K was 1.30 cmol/kg. After the experiment, exchangeable K of pot contaminated with kerosene varied from 1,03 to 1.24 cmol/kg with a mean of 1.16 cmol/kg Exchangeable K of pot contaminated with crude oil varied from 0.94 to 1.0 cmol/kg with a mean of 1 0. cmol/kg while exchangeable K of pot contaminated with engine oil varied from 0.98 to 1.21 cmol/kg with a mean of 1.12 cmol/kg. Mean exchangeable k before the experiment was significantly higher ($p < 0.05$) than that of pots contaminated with engine oil and crude oil after the experiment. Mean exchangeable k was high before the experiment and varied from moderate to high after the experiment. The reduction in exchangeable K could be attributed to microbes that utilize TPH as carbon source, may also utilize exchangeable K when they degrade hydrocarbon (Wang *et al*., 2009). Before the experiment, exchangeable acidity was 1.93 cmol/kg. After the experiment, exchangeable acidity of pot contaminated with kerosene varied from 1.84 to 1.94 cmol/kg with a mean of 1.89 cmol/kg Exchangeable acidity of pot contaminated with crude oil varied from 1.94 to 2.0 cmol/kg with a mean of 1.97 cmol/kg while exchangeable acidity of pot contaminated with engine oil was 1.84 cmol/kg. Mean exchangeable acidity before the experiment was significantly higher ($p < 0.05$) than that of pots contaminated with kerosene and engine oil after the experiment. The reduction in exchangeable acidity could be attributed to association of oil pollution with accumulation of exchangeable bases which reduces potential acidity (Osuji et al., 2004).Before the experiment, ECEC was 6.63 cmol/kg. After the experiment, ECEC of pot contaminated with kerosene varied from 5.38 to 5.69 cmol/kg with a mean of 5.53. cmol/kg. ECEC of pot contaminated with crude oil varied from 5.36 to 5.68 cmol/kg with a mean of 5.47. cmol/kg while ECEC of pot contaminated with engine oil varied from 5.13 to 5.31 cmol/kg with a mean of 5.23 cmol/kg. Mean ECEC before the experiment was significantly higher ($p < 0.05$) than that of pots contaminated with kerosene, crude oil and engine oil after the experiment. The reduction in ECEC could be attributed to association of oil pollution with accumulation of exchangeable bases which reduces potential acidity and effective cation exchange capacity (Osuji, 2006).Before the experiment, base saturation was 70.92 %. After the experiment, base saturation of plot contaminated with kerosene varied from 64.7 to 66.9 % with a mean of 65.8 %. Base saturation of pot contaminated with crude oil varied from 62.7 to 65.1 % with a mean of 63.9 % while base saturation of pot contaminated with engine oil varied from 64.1 to 67.4 % with a mean of 65.5 %. Base saturation of pots contaminated with kerosene, engine oil and crude oil after the experiment were significantly lower ($p < 0.05$) than before the experiment. Base saturation was high before the experiment and moderate after the experiment. The reduction in base saturation could be attributed to microbes that utilize TPH as carbon source, may also utilize exchangeable bases when they degrade hydrocarbon (Wang *et al*., 2009).

### Effect of polluted soil on growth and yield of maize

Effect of polluted soil on growth and yield of maize is presented in figure 1-7 and (Table 2).

**Table 2:** Effect of polluted soil on growth and yield of maize.

| Treatment | Rate | Germination rate | Number of leaves | Plant height (cm) | Leave length (cm) | Stem girth | Fresh weight (g) | Dry weight (g) |
|---|---|---|---|---|---|---|---|---|
| **Control** | | 19.80g | 3.7de | 6.17gh | 14.80ghl | 0.88h | 33.37e | 8.12g |
| **Kerosene** | 40ml | 1.57c | 3.12cd | 5.72fg | 12.41fg | 0.51defg | 6.54ab | 3.3e |
| | 60ml | 1.20bc | 2.80bc | 5.40f | 8.76d | 0.65fgh | 5.62ab | 2.73de |
| | 80ml | 1.23bc | 2.20b | 4.23de | 6.2c | 0.38cd | 5.40ab | 1.53de |
| | 100ml | 0.197ab | 0.57a | 1.13b | 4.4b | 0.27bc | 4.48ab | 1.17abc |
| **Engine oil** | 40ml | 4.5f | 2.33b | 4.23de | 12.90fgh | 0.75gh | 10.41bc | 3.53e |
| | 60ml | 3..5def | 2.67bc | 3.63d | 11.9f | 0.71fgh | 6.25ab | 1.57bcd |
| | 80ml | 3.9ef | 2.47b | 2.80c | 11.5ef | 0.56defg | 4.5ab | 1.80cd |
| | 100ml | 2.7d | 2.17b | 2.43c | 10.2e | 0.42cdf | 3.02a | 1.0abc |
| **Crude oil** | 40ml | 3.1de | 2.30b | 4.17de | 12.67fgh | 0.42cdef | 14.02c | 3.15e |
| | 60ml | 2.7d | 2.27b | 3.9de | 11.9f | 0.23bc | 3.85ab | 1.78cd |
| | 80ml | 1.4c | 2.30b | 2.83c | 8.67d | 0.13ab | 3.06a | 0.33ab |
| | 100ml | 0.00a | 0.00a | 0.00a | 0.00a | 0.00a | 0.00a | 0.00a |

Means with the same letter along the row are not significant at 5 % level

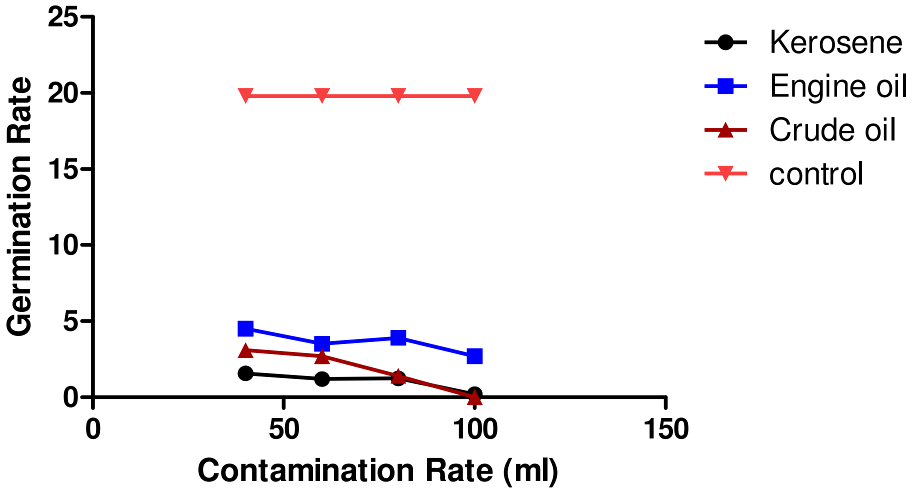

**Figure 1**: Effect of oil pollution on the germination of maize.

Germination rate was significantly higher ($p < 0.05$) in the control (19.80) than all the contaminated plots (Table 2). Germination rate decreases with increasing contamination rate (Figure 1). The trend was control > 40 ml > 60 ml > 80ml > 100 ml. Among pollutants, engine oil > crude oil > kerosene. The decrease in germination rate could be attributed to insufficient aeration of the soil because of displacement of air from spaces between the soil particles by contaminated oil. Number of leaves were significantly higher ($p < 0.05$) in the control (3.7) than all the contaminated pots. Number of leaves decreased with increasing contamination rate (Fig. 2). The trend was control 40 ml > 60 ml > 80ml > 100 ml. Among pollutants, kerosene > engine oil > crude oil. The decrease in number of leaves due to effect of contamination could be attributed to dehydration of the plant by the oil, as well as interference in uptake of nutrients by plant (Baek *et al.* 2005). Plant height was significantly higher ($p < 0.05$) in the control (6.17 cm) than all the contaminated pots. Plant height decreases with increasing contamination rate (Figure 3). The trend was 0 ml > 40 ml > 60 ml > 80ml > 100 ml. Among pollutants, control > kerosene > engine oil > crude oil. The decrease in plant height could be attributed to interference of nutrients uptake by contaminated oil, resulting in stunted growth (Baek *et al.* 2005). Stem girth was significantly higher ($p < 0.05$) in the control (0.8 cm) than all the contaminated pots. Stem girth decreases with increasing contamination rate (Figure 4). The trend was 0 ml >40 ml > 60 ml > 80 ml > 100 ml. Among pollutants, engine oil < kerosene < crude oil < control. The decrease in stem girth could be attributed to the competition of little nutrients between plants and microbes, which ultimately suppresses the growth of the pant. Leaf length was significantly higher

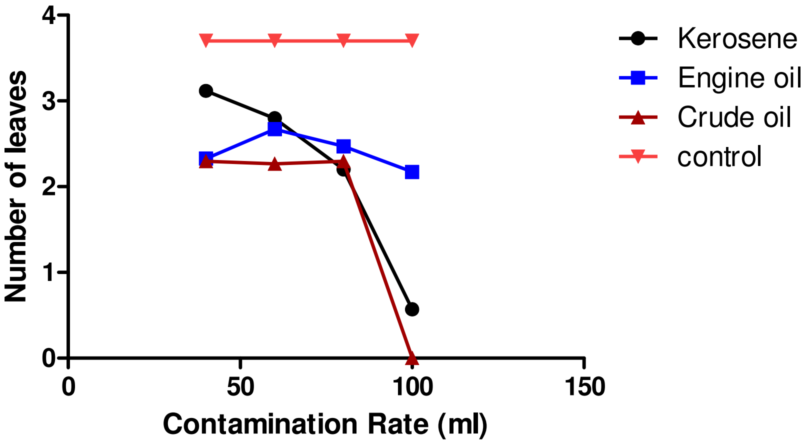

**Figure 2:** Effect of oil pollution on the number of leaves of maize.

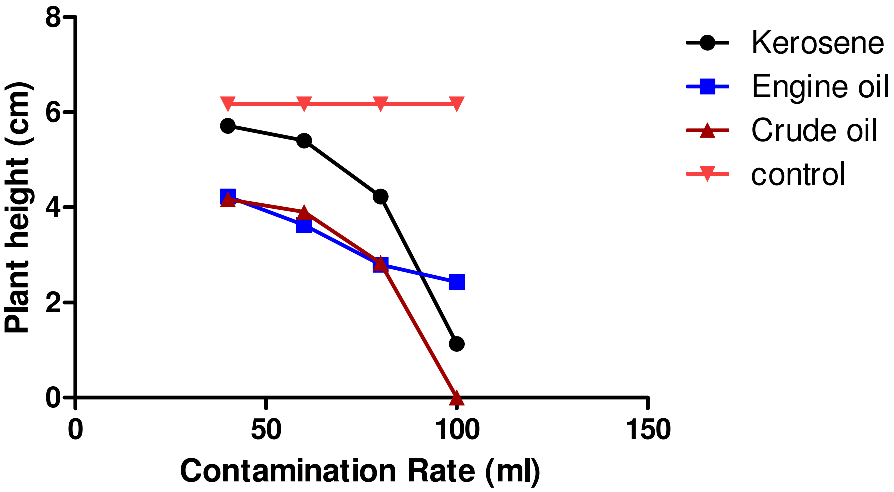

**Figure 3:** Effect of oil pollution on plant height.

($p < 0.05$) in the control (14.80 cm) than all the contaminated pots. Leaves length decreases with increasing contamination rate (Figure 5). The trend was 0 ml >40 ml > 60 ml > 80ml > 100 ml. Among pollutants, engine oil > kerosene > crude oil. The decrease in leave length could be attributed to the blockage of conducting tissues, thereby preventing water and nutrients uptake and limiting growth of leave length. Fresh weight of maize was significantly higher ($p < 0.05$) in the control (33.37g) than all the contaminated pots. Leaves length decreases with increasing contamination rate (Figure 6). The trend was 0 ml >40 ml > 60 ml > 80ml > 100 ml. Among pollutants, crude oil > engine oil > kerosene. The decrease in fresh weight could be attributed to the competition of little nutrients between plants and microbes, which ultimately suppresses the growth of the plant. Dry weight of maize was significantly higher ($p < 0.05$) in the control (8.12g) than all the contaminated pots. Dry weight decreases with increasing contamination rate (Figure 7). The trend was 0 ml >40 ml > 60 ml > 80ml > 100 ml. Among pollutants,> engine oil > kerosene > crude oil. The decrease in dry weight could be attributed to the competition of little nutrients between plants and microbes, which ultimately suppresses the growth of the plant.

### Relationship between soil properties of contaminated plot and growth and yield of maize

The relationship between soil properties and growth and yield of maize in plots contaminated with kerosene, engine oil and crude oil are presented in (Tables 3).

**Table 3:** Relationship between growth and yield parameters with soil properties.

| | | **Germinat** | **No_leaf** | **Pl_height** | **leaf_length** | **Stem_girth** | **Fresh_wt** | **Dry_wt** |
|---|---|---|---|---|---|---|---|---|
| sand | Pearson | -0.467 | -0.462 | -0.537 | -.765$^{**}$ | -0.262 | -0.469 | -0.575 |
| | Sig. | 0.126 | 0.131 | 0.072 | 0.004 | 0.410 | 0.124 | 0.051 |
| | N | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| silt | Pearson | -0.196 | 0.385 | 0.363 | 0.509 | -0.158 | -0.161 | -0.011 |
| | Sig. | 0.541 | 0.216 | 0.247 | 0.091 | 0.623 | 0.617 | 0.973 |
| | N | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| clay | Pearson | 0.594$^{*}$ | 0.556 | .650$^{*}$ | .860$^{**}$ | 0.329 | .608$^{*}$ | .680$^{*}$ |
| | Sig. | 0.042 | 0.060 | 0.022 | 0.000 | 0.297 | 0.036 | 0.015 |
| | N | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| pH | Pearson | 0.843$^{**}$ | -0.419 | -0.511 | -0.296 | -.611$^{*}$ | -.824$^{**}$ | -.751$^{**}$ |
| | Sig. | 0.001 | 0.176 | 0.089 | 0.351 | 0.035 | 0.001 | 0.005 |
| | N | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| EC | Pearson | -0.791$^{**}$ | -0.503 | -0.479 | -0.291 | -0.492 | -0.784$^{**}$ | -0.689$^{*}$ |
| | sign | 0.002 | 0.096 | 0.115 | 0.359 | 0.104 | 0.003 | 0.013 |
| | N | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| TN | Pearson | -0.390 | -0.427 | -0.601$^{*}$ | -0.736$^{**}$ | -0.163 | -0.405 | -0.462 |
| | Sig. | 0.210 | 0.166 | 0.039 | 0.006 | 0.614 | 0.192 | 0.130 |
| | N | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| AvP | Pearson | 0.797$^{**}$ | 0.150 | 0.302 | 0.129 | 0.441 | 0.760$^{**}$ | 0.640$^{*}$ |
| | Sig. | 0.002 | 0.642 | 0.340 | 0.689 | 0.152 | 0.004 | 0.025 |
| | N | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| OC | Pearson | -0.517 | 0.014 | 0.005 | -0.081 | 0.000 | -0.498 | -0.350 |
| | Sig. | 0.085 | 0.965 | 0.989 | 0.802 | 1.000 | 0.099 | 0.265 |
| | N | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| Ca | Pearson | -0.663$^{*}$ | 0.027 | -0.197 | -0.233 | -0.113 | -0.627$^{*}$ | -0.485 |
| | Sig. | 0.019 | 0.935 | 0.539 | 0.467 | 0.726 | 0.029 | 0.110 |
| | N | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| Mg | Pearson | 0.981$^{**}$ | 0.629$^{*}$ | 0.754$^{**}$ | 0.678$^{*}$ | 0.677$^{*}$ | 0.971$^{**}$ | 0.963$^{**}$ |
| | Sig. | 0.000 | 0.029 | 0.005 | 0.015 | 0.016 | 0.000 | 0.000 |
| | N | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| Na | Pearson | -0.784$^{**}$ | -0.464 | -0.529 | -0.610$^{*}$ | -0.309 | -0.783$^{**}$ | -0.725$^{**}$ |
| | Sig. | 0.003 | 0.129 | 0.077 | 0.035 | 0.329 | 0.003 | 0.008 |
| | N | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| K | Pearson | 0.684$^{*}$ | 0.311 | 0.476 | 0.586$^{*}$ | 0.406 | 0.680$^{*}$ | 0.658$^{*}$ |
| | Sig. | 0.014 | 0.325 | 0.118 | 0.045 | 0.191 | 0.015 | 0.020 |
| | N | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| EA | Pearson | 0.216 | 0.442 | 0.515 | 0.354 | 0.333 | 0.219 | 0.318 |
| | Sig. | 0.499 | 0.150 | 0.087 | 0.259 | 0.290 | 0.494 | 0.313 |
| | N | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| ECEC | Pearson | 0.959$^{**}$ | 0.660$^{*}$ | 0.794$^{**}$ | 0.734$^{**}$ | 0.702$^{*}$ | 0.953$^{**}$ | 0.966$^{**}$ |
| | Sig. | 0.000 | 0.019 | 0.002 | 0.007 | 0.011 | 0.000 | 0.000 |
| | N | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| BS | Pearson | 0.899$^{**}$ | 0.551 | 0.610$^{*}$ | 0.605$^{*}$ | 0.655$^{*}$ | 0.892$^{**}$ | 0.866$^{**}$ |
| | Sig. | 0.000 | 0.064 | 0.035 | 0.037 | 0.021 | 0.000 | 0.000 |
| | N | 12 | 12 | 12 | 12 | 12 | 12 | 12 |

** = significant at 5 % level; * = significant at 10 % level

Germination rate, negatively correlated with soil pH (r = -0.84), Electrical conductivity (r = -0.71) and Na (r = -0.78) but positively correlated with available P (r = 0.79), exchangeable Mg (r = 0.98), exchangeable K (r = 0.68), ECEC (r = 0.95) and base saturation (r = 0.89). This shows that the higher the clay fraction, available P, exchangeable Mg, K, base saturation and ECEC in the soil, the higher the germination rate. The higher the electrical conductivity and soil pH, the slower the germination rate. The number of leaves had a positive correlation with exchangeable Mg (r = 0.63) and a substantial positive correlation with exchangeable ECEC (r = 0.66). This shows that the higher the exchangeable Mg and ECEC in the contaminated soil, the higher the number of leaves. Plant height were positively correlated with clay (r = 0.65) negatively correlated with total N (r = -60) positively correlated with exchangeable Mg (r = 0.85); positively correlated with exchangeable Mg (r = 0.75); positively correlated with ECEC (r = 0.79) and positively correlated with base saturation (r = 0.61). This shows that the higher the clay fraction, exchangeable Mg, ECEC and base saturation in the contaminated soil, the higher the plant height. The lower the total N, the more the plant height. Leave length were positively correlated with clay Mg, K. ECEC & Base Saturation but negatively correlated with Sand and Na. This shows that the higher the clay fraction, exchangeable Mg, K, ECEC and base saturation in the contaminated soil, the higher the leave length. The lower the total N, exchangeable Na, and sand fraction, the higher the leave length. Stem girth were positively

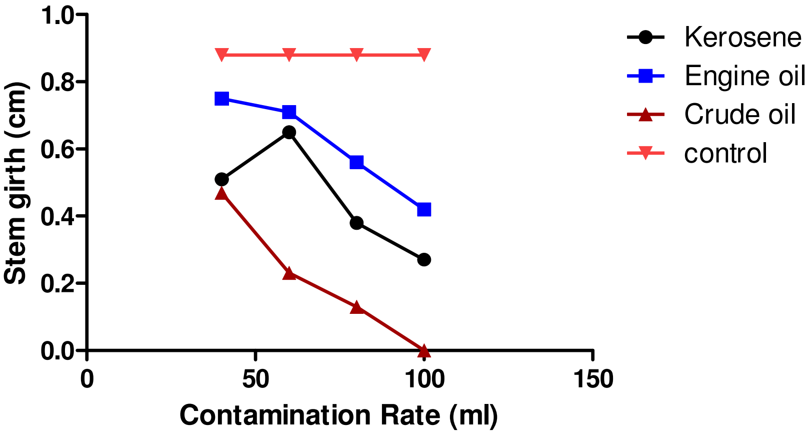

**Figure 4:** Effect of oil pollution on stem girth of maize.

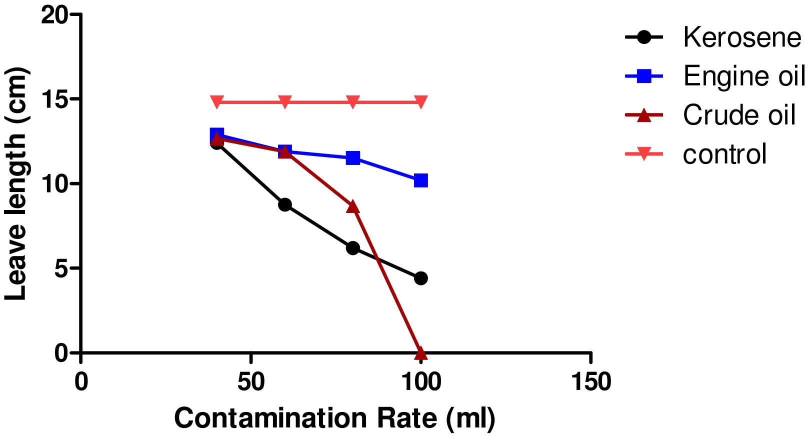

**Figure 5.** Effect of oil pollution on of maize.

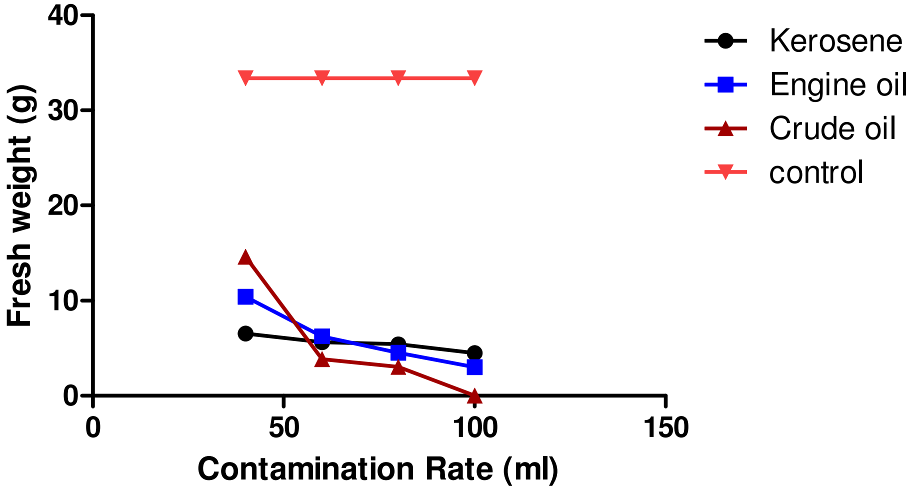

**Figure 6:** Effect of oil pollution on fresh weight of maize.

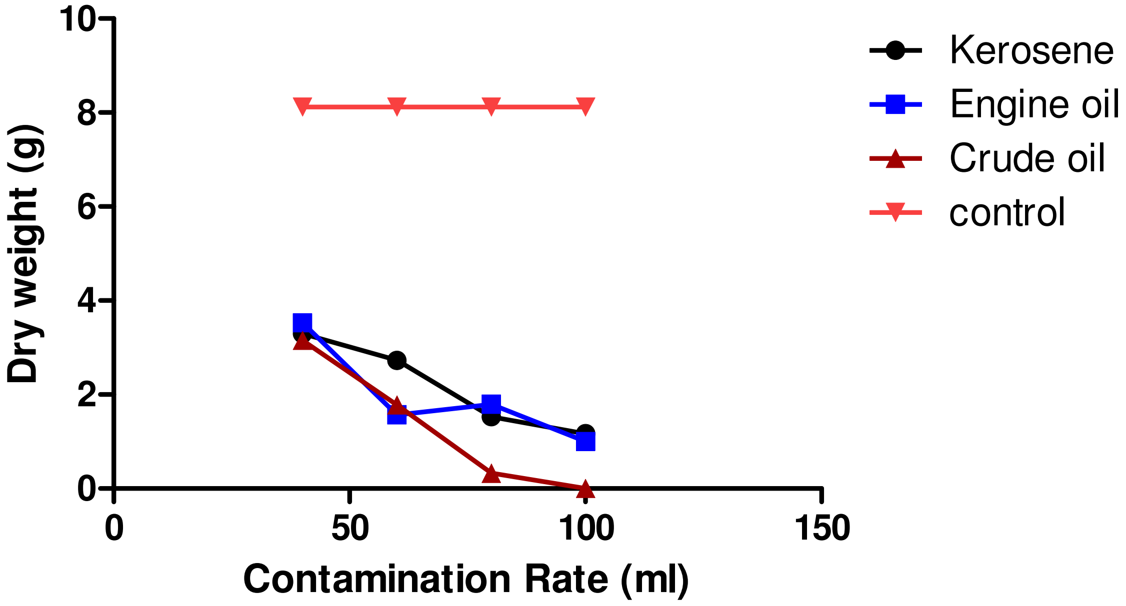

**Figure 7:** Effect of oil pollution on dry weight of maize.

correlated with exchangeable Mg, ECEC, Base saturation. This shows that the higher the exchangeable Mg, ECEC and base saturation in the contaminated soil, the higher the stem girth. Fresh weight was and negatively correlated with soil pH, Na, Ca, but positively correlated with clay, available P. This shows that the higher the clay fraction, available P, exchangeable Mg, K, base saturation and ECEC in the soil, the higher the fresh weight. The higher the electrical conductivity, Ca, Na and soil pH, the lower the fresh weight. Dry weight was and negatively correlated with soil pH, EC, Na but correlated positively with P, mg, K, Base Saturation and ECEC. This shows that the higher the clay fraction, available P, exchangeable Mg, K, base saturation and ECEC in the soil, the higher the dry weight. The higher the electrical conductivity, Na and soil pH, the lower the dry weight.

## Conclusion and recommendation

The study revealed that Kerosene, crude oil and engine oil contamination significantly raised the electrical conductivity, organic carbon, total Nitrogen, exchangeable Ca, exchangeable Na content of the soil and reduced soil pH, available P, exchangeable Mg, K, potential acidity, ECEC and base saturation. Germination rate, number of leaves, plant height, leave length, stem girth, fresh weight and dry weight decreased with increasing contamination rate. Further investigation should be carried out to identify plant that can tolerate crude oil pollution, and remediation should be carried out to regain the originality of the soil.

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