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Performance Of Zea Mays On Soil Contaminated With Petroleum (Oily) Sludge

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***Abstract:** The study on the performance of Zea mays on soil contaminated with petroleum (oily) sludge was carried out using petroleum sludge sample from Kolocreek Rig in Port-Harcourt, Rivers State of Nigeria. Different concentrations of sludge contamination on soil were prepared and yellow and white maize seeds planted on them. Sludge and soil samples were subjected to laboratory analysis to determine their heavy metal concentrations (Nickel, Lead, Cadmium and Chromium) and total petroleum hydrocarbon (TPH) content, using Atomic Absorption Spectroscopy (AAS). Physical parameters of maize plants (plant height and average leaf width) were measured on weekly basis to determine the physical performance of the maize plant on petroleum sludge-contaminated soil using calibrated meter rule. Yellow and white maize seeds planted on uncontaminated soil (0% sludge) had 100% germination, seeds on 10% sludge had 75% and 50% germination respectively for yellow and white maize; seeds on 25% sludge had 25% germination each for the two maize types. Soil-plant transfer factor or bioaccumulation factor, f of the heavy metals by the plant showed that maize plant was able to take up the heavy metals from the soil (for example, f-value for Cr = 0.83 in 10% sludge, Ni = 0.91 in 25% sludge, Cd = 0.77 in 5% sludge, etc). Petroleum (oily) sludge contamination had significant effect on the general performance of Zea mays (p > 0.05). Maize plant has the ability to bioaccumulate (take-up) heavy metals and hydrocarbons from the soil thus possess high phytoremediation potential.*

***Keywords:** Performance, Zea mays, Soil, Contaminated, Petroleum sludge*

I. INTRODUCTION

The common reference to oil as "black gold" is apt. Apart from the fact that gold connotes wealth and what is worthwhile, black is associated with "evil" and Nigeria has experienced this dual appellation ascribed to oil. Oil has brought a lot of wealth to the nation, as it is a major foreign exchange earner for Nigeria. It has boosted the economy by reducing unemployment, providing raw materials for local industries and for export. Though the oil industry is an enclave economy, it has nevertheless provided some forward and backward linkages in the economy. Indeed, since the 1970s, oil has remained the lich-pin of the nation's economic life, powering growth and development.

Nigeria is a major producer and exporter of crude petroleum oil as well as an important agricultural nation in the West African sub-region (Agbogidi *et al*, 2005). While the benefits of the oil industry are not in doubt, the exploration, development and production of oil and gas generate wastes which include among others the following; drilling cuttings, drilling fluids, produced water, completion and work-over fluids, trace metals, heat waste, oxides of Carbon, Sulphur and Nitrogen, and petroleum (oily) sludge (EPA, 1991).

Petroleum (oily) sludge is one of the most significant solid wastes generated in the petroleum industry. It is a complex emulsion of various petroleum hydrocarbons (PHCs), water, heavy metals, and solid particles. Due to its hazardous nature and increased generation quantities around the world, the effective treatment of oily sludge has attracted widespread attention. A considerable amount of oily sludge can be generated from the petroleum industry during its crude oil exploration, production, transportation, storage and refining processes (Xu *et al*., 2009; Marin *et al*., 2005). In particular, the sludge generated during the petroleum refining process has received increasing attention in recent years. It contains a high concentration of petroleum hydrocarbons (PHCs) and other recalcitrant components. As being recognized as a hazardous waste in many countries, the improper disposal or insufficient treatment of oily sludge can pose serious threats to the environment and human health (Xu *et al.*, 2009; Da Rocha *et al*., 2010). A huge amount of oily sludge is also generated during the cleaning up of crude oil storage tanks, maintenance of associated facilities and pre-export processing activities of crude oil at ocean terminals (that is, tank farms). Because oily sludge contains toxic substances like aromatic hydrocarbons (benzene, toluene, ethyl benzene and xylene), poly-aromatic hydrocarbons (Swoboda-Colberg, 1995), and high total hydrocarbon content (Ayotamuno *et al.*, 2007), its disposal without adequate treatment leads to environmental, particularly soil pollution. Apart from recent socio-economic problems like militancy and kidnapping, occasioned by the neglect of their corporate social responsibilities, humans and ecosystem may be exposed to chemical hazards such as heavy metals (Lead, Chromium, Arsenic, Zinc, Cadmium, Copper, Mercury and Nickel) through the direct ingestion of contaminated soils, consumption of crops and vegetables grown on the contaminated lands or drinking water that has percolated through such soils (McLaughlin *et al.*, 2000). There is therefore the need to effect proper treatment to petroleum sludge before disposal or reuse. The treatment of this oily sludge has become one of the major problems facing crude oil-producing multinational companies operating in developing countries like Nigeria. This is because, the officially recommended treatment method, incineration, is prohibitively expensive (DPR, 2002; Shkidchenko *et al.*, 2004) and exposes personnel and equipment to the resulting fugitive dusts. Consequently, it is important to adopt a cheaper and much more ecologically sound treatment technique for this type of petroleum waste.

During the past years, a variety of oily sludge treatment methods have been developed, such as land-farming, incineration, solidification/stabilization, solvent extraction, ultrasonic treatment, pyrolysis, photocatalysis, chemical treatment, and biodegradation (Xu *et al*, 2009; liu *et al.*, 2009). By employing these technologies, the contents of hazardous constituents can be reduced or eliminated, and its deleterious environmental and health impacts can thus be mitigated. However, due to the recalcitrant nature of oily sludge, few technologies can reach a compromised balance between satisfying strict environmental regulations and reducing treatment costs. As a result, there is a need for a comprehensive discussion of current oily sludge treatment methods to identify their advantages and limitations.

In recent times, several literatures have shown that bioremediation has high potentials for restoring polluted media with least negative impact on the environment at relatively low cost. Bioremediation, the basis of which may date back to the work of Atlas and Bartha (1972), is the use of microorganisms (bacteria and fungi) to accelerate the natural decomposition of hydrocarbon contaminated waste into non-toxic residues. This technology has been used in bio-treating exploration and production (E&P) wastes (McMillen *et al.*, 2004).

However, intrinsic bioremediation has been observed to be a very slow process, which could take years to yield the desired results (Mitchell *et al.*, 2000; Wills, 2000). To remedy this situation, taking into account overall costs and operational time, numerous researchers have demonstrated high bioremediation efficiency for oil polluted soils by adopting various strategies to aid bioremediation (Okolo *et al.*, 2005; Ayotamuno *et al*., 2006).

However, these methods have limitations for an oily sludge, which is mainly characterized by extremely high pollution levels and contaminants recalcitrant to bioremediation such as polycyclic aromatic hydrocarbons (PAHs) with more than five rings (Allard and Neilson, 1997). This may be partly because indigenous bacteria in the soil can degrade target constituents of oily sludge only to an extent dependent on their abundance or deficiency in the medium especially, when the contaminants are present at high concentrations (Mishra *et al.*, 2001). Pollution is generally believed to be a necessary price for the development ushered in by the petroleum industry and this has adversely affected the production of agricultural crops like maize.

Maize *(Zea mays* L.*)*, or corn is a versatile cereal crop that is grown widely throughout the world in a range of agro-ecological environments. Maize is the most important cereal crop in sub-Saharan Africa (SSA) and an important staple food for more than 1.2 billion people in SSA and Latin America (IITA, 2010). In Nigeria, maize is the most important staple cereal after sorghum and millet with the widest geographical spread in terms of production and utilization among the cereals (Omoloye, 2009). Maize is grown in all parts of the country, though it is grown slightly more in the savannah belt of the country. About 50 species exist and consist of different colors, textures and grain shapes and sizes. White, yellow and red are the most common types. All parts of the crop can be used for food and non-food products (IITA, 2010). Production and utilization of maize has increased in Nigeria in recent years as a result of the introduction of high yielding, drought tolerant, early and extra early maturing varieties (example 80 to 90 days) (FEWS NET, 2006).

High heavy metal accumulating ability has been reported for cereal crops such as Maize (*Zea mays* L.), Sorghum (*Sorghum bicolor*), Alfalfa (*Medicago sativa* L.) (Vijayarengan, 2005). This attribute can be used as an indicator of the level of soil contamination and in the passive monitoring of the environment (Wong, 1996) and even offer phytoremediation potential. Maize particularly is a widely cropped annual cereal that grows rapidly, produces extensive fibrous root system with large biomass, withstands adverse conditions, produces abundant seeds with ease of cultivation under repeated cropping (Garbisu and Alkorta, 2001; Jadia and Fulekar, 2008; Zhang *et al*, 2009).

Maize is capable of continuous phytoextraction of heavy metals from contaminated soils by translocating them from roots to shoots ((Nascimento et al., 2006). The soil-plant transfer factor or bioaccumulation factor, *f*, expressed as the ratio of plant metal concentration divided by the total metal concentration in soil, and amount of biomass produced per hectare may be used as indicators of the plant accumulation behaviour (Kabata-Pendias and Pendias, 2001; Kimenyu *et al*, 2009). The higher the *f* -factor, the more effective is the phytoextractor. Normal transfer coefficients in maize have been reported as: Zn, 1 – 2; Cd, Cu and Pb, 0.01 – 0.05 (Korentejar, 1991), but these have been shown to actually vary for contaminated soils: Zn, 0.82; Cd, 3.33; Cu, 1.08; Pb, 0.07 (Mathe-Gaspar and Anton, 2005) and Zn, 0.23; Cd, 0.18; Cu, 0.15; Pb, 0.12 (Wuana *et al.*, 2010). The maize plant has been even shown to accumulate certain heavy metals such as Cd (Kimenyu *et al.*, 2009) and Pb (Pereira *et al.*, 2007) above levels that define metal hyper-accumulation. Based on its capability of heavy metal uptake and sensitivity to high metal pollution, Mathe-Gaspar and Anton (2005) have grouped maize as an accumulator and a metal tolerant plant especially for Cd and Zn. The ideal soil types for maize plant are loam or silt loam surface soil and brown silt clay loam having fairly permeable sub soil (IKSAN, 2000). The time period of growth of maize plant can significantly affect both *f* and biomass yield of maize. The normal time for maturity of maize plant is 120 days, although in improved varieties, this has been shortened to 80 – 90 days or even less. A number of investigations have studied heavy metal uptake by maize grown in contaminated soils for different time periods, namely: 21 days (Peciulyte *et al.*, 2006), 30days (Kimenyu *et al.*, 2009), 35 days (Wuana *et al.*, 2010), 45 days (Chahab and Savaghebi, 2010), 60 days (Zhang *et al.*, 2009; Kimenyu *et al.*, 2009) and 90 days (Kimenyu *et al.*, 2009).

It has been suggested, however, that the highest metal accumulation by maize can possibly be achieved within a short time period (21 – 30days) of planting (Peciulyte *et al.*, 2006; Kimenyu *et al.*, 2009). This means that leaving the maize plant to grow in contaminated soils for an extended time period will lower *f* probably due to increased plant biomass, resulting to an increased distribution of the heavy metal over the whole plant (Kimenyu *et al.*, 2009). The level of heavy metal in the contaminated soil can also influence *f* and biomass yield of maize.

AIM OF STUDY: To determine the physical performance of *Zea mays* on soil contaminated with petroleum (oily) sludge and the heavy metal uptake (phytoremediation) of the plant.

A. OBJECTIVES OF STUDY

- ✓ To determine the effect of different concentrations of petroleum sludge on the rate of germination of maize
- ✓ To determine the effect of different concentrations of petroleum sludge on the general performance of maize
- ✓ To determine the bioaccumulaion factor, f (phytoremediation ability) of maize plant

B. RESEARCH HYPOTHESIS

- ✓ H0: Different concentrations of petroleum (oily) sludge have no significant effect on the rate of germination of *Zea mays*
- ✓ H0: Different concentrations of petroleum (oily) sludge have no significant effect on the physical performance of *Zea mays* considering the following parameters: stem length, Height and leaf width

II. MATERIALS AND METHODS

A. SAMPLE COLLECTION

Twenty-five liters of petroleum (oily) sludge was collected for this study in a bucket from Kolocreek rig in Port-Harcourt, Rivers State of Nigeria. The soil sample used for this study was collected using a shovel and bucket from a virgin loamy soil in Ezeala Avenue, Oyibo Rivers State of Nigeria.

B. SAMPLE PREPARATION

The soil sample was measured into different pots using the measuring scale and different quantities of the petroleum (oily) sludge were added to the pots and mixed thoroughly thus contaminating the soil samples with different concentrations of the sludge ranging from an uncontaminated soil (0% sludge) to pure sludge (100% sludge).

Table 3.1 shows the different masses of soil and sludge mixed to form the various Soil: Sludge ratios using the formula:

$$a/x = b/y$$

Where: a = Soil percentage, b = sludge percentage, x = soil mass (kg) and y = sludge mass (kg).

Percentage concentration of sludge	Soil mass (kg)	Sludge mass (kg)	Soil : Sludge Ratio (%)
0%	4.5	0	100:0
5%	4.5	0.24	95:5
10%	4.5	0.5	90:10
15%	4.5	0.8	85:15
20%	4.5	1.13	80:20
25%	4.5	1.5	75:25
30%	4.5	1.9	70:30
50%	4.5	4.5	50:50
70%	1.9	4.5	30:70
90%	0.5	4.5	10:90
100%	0	4.5	0:100

Table 2.1: Sample Preparation Schedule Table

C. PLANTING OF MAIZE SEEDS

Four (4) healthy seeds each of yellow and white maize were planted at different points in each pot and properly labeled and watered twice a day (morning and evening).

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D. WEEKLY MEASUREMENTOF PHYSICAL PARAMETERS

On weekly basis, the stem length, height and leaf width of a plant each for yellow and white maize in each bed were measured using calibrated m/cm ruler (as illustrated in the figure below)

E. LABORATORY ANALYSIS

The following analyses were carried out on the samples

- ✓ Heavy metal analysis on the petroleum (oily) sludge and soil samples for Chromium, Nickel, Lead and Cadmium
- ✓ Total petroleum hydrocarbon analysis on the sludge and soil samples
- ✓ Heavy metal analysis on each bed sample for Chromium, Nickel, Lead and Cadmium after the experiment
- ✓ Total petroleum hydrocarbon analysis on each bed after the experiment

a. HEAVY METAL AND TOTAL PETROLEUM HYDROCARBON (TPH) ANALYSIS

The heavy metals determined were: Chromium, Nickel, Lead and Cadmium. The soil and sludge samples were extracted with 50ml of extracting solution and shaken in a reciprocating shaker for two hours. The samples were centrifuged at 3000rpm for 15 minutes and the supernatants were used for the determination of the heavy metals (Chromium, Nickel, Lead and Cadmium) and TPH using BUCK205 Atomic Adsorption Spectrophotometer (AAS).

III. RESULTS

A. RATE OF GERMINATION

Table 4.1 shows the rate of germination of the uncontaminated soil (0% sludge) and other percentage sludge contaminations (5%, 10%, 15%, 20%, 25%, 30%, 50%, 70%, 90% and 100% sludge). The table shows that yellow and white maize had 100% germination in pots without sludge (0% sludge) and the various concentrations of sludge contamination significantly affected the rate of maize germination. From 5% to 25%, the rate of germination dropped simultaneously as the concentration of sludge contamination increased. From 30% sludge to 100% sludge showed no germination at all.

BED (% sludge)	YELLOW MAIZE	WHITE MAIZE
0%	4 (100%)	4 (100%)
5%	3 (75%)	3 (75%)
10%	3 (75%)	2 (50%)
15%	2 (50%)	1 (25%)
20%	2 (50%)	2 (50%)
25%	1 (25%)	1 (25%)
30%	No germination (0%)	No germination (0%)
50%	No germination (0%)	No germination (0%)
70%	No germination (0%)	No germination (0%)
90%	No germination (0%)	No germination (0%)
100%	No germination (0%)	No germination (0%)

Table 3.1: Percentage germination of maize seeds after five (5) days

B. RESULT OF WEEKLY MEASUREMENT OF PHYSICAL PARAMETERS

Tables 2 and 3 show the results of the weekly measurements of the height and average width of leaves of maize plants for thirteen (13) weeks. The results show that as the concentration of sludge increases, the length and average width of leaves decreased. The highest value (71.2cm) of Maize plant hieght was recorded in bed without sludge while the least value (24.7cm) was recorded in bed with 25% sludge. the sludge contamination adversely affected these parameters for instance in table 2, week 7, yellow and white maize had stem length 27.3cm and 20.1cm respectively in the uncontaminated soil (0% sludge) but had 13.9cm and 12.5cm stem length respectively in 20% sludge concentration.

% conc. of sludge	Maize type	Week												
		1	2	3	4	5	6	7	8	9	10	11	12	13
0	Y	15.3	25.7	32.3	43.2	48.0	51.1	53.3	58.2	58.2	59.5	68.0	70.8	71.2
	W	17.1	28.1	30.1	31.1	36.0	45.2	45.9	50.6	51.2	53.0	57.5	50.1	49.3
5	Y	18.9	25.5	29.1	32.6	39.3	47.1	51.7	60.0	60.9	61.1	61.2	62.8	68.7
	W	18.0	19.5	21.9	23.4	28.7	30.3	32.1	33.0	35.3	35.8	36.5	38.1	39.1
10	Y	13.5	23.5	25.3	25.3	35.8	37.4	40.1	43.7	46.7	47.2	47.9	49.3	49.5
	W	13.9	18.0	25.1	26.2	43.2	43.2	43.5	44.5	50.2	53.2	61.3	62.3	62.3
15	Y	10.8	16.7	19.4	25.5	27.3	29.5	40.1	41.5	46.1	46.9	48.0	47.1	45.8
	W	9.9	17.1	18.0	20.1	28.8	30.4	33.8	36.2	36.6	36.8	36.1	36.0	35.5
20	Y	10.1	11.8	13.6	15.0	16.1	16.7	22.1	23.8	24.2	25.3	26.1	26.9	27.7
	W	10.0	16.8	23.4	24.0	24.4	25.0	27.1	28.2	29.1	30.3	31.1	31.6	32.0
25	Y	8.4	11.3	18.0	18.1	18.2	19.0	20.0	20.1	21.1	22.0	23.3	24.0	24.7
	W	7.7	15.5	16.0	16.0	16.2	17.7	20.3	20.5	20.9	23.1	24.5	25.0	25.5

Key: W = White maize, Y = Yellow maize

Table 3.2: Height (cm) of Zea mays grown on soil contaminated with different concentrations of sludge

% conc. of sludge	Maize type	Week												
		1	2	3	4	5	6	7	8	9	10	11	12	13
0	Y	1.4	1.6	2.1	2.3	2.5	2.6	3.0	3.2	3.3	3.5	3.6	3.7	3.8
	W	1.4	1.6	1.8	2.2	2.3	2.4	2.6	2.8	2.9	3.4	3.9	4.3	4.7
5	Y	1.1	1.2	1.3	1.5	1.8	1.9	2.0	2.5	2.6	2.5	2.5	2.4	2.4
	W	1.0	1.0	1.1	1.2	1.3	1.4	1.5	1.7	1.8	1.9	2.0	2.0	1.9
10	Y	1.6	1.7	2.1	2.1	2.3	2.4	2.4	2.5	2.0	2.0	1.8	1.8	1.5
	W	1.8	1.8	1.8	1.9	2.0	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.2
15	Y	1.2	1.6	1.7	1.8	2.3	2.5	2.6	2.8	3.0	3.0	2.9	2.7	2.5
	W	1.1	1.1	1.2	1.3	1.3	1.4	1.4	1.6	1.8	1.9	1.9	1.8	1.7
20	Y	1.0	1.0	1.1	1.1	1.2	1.3	1.4	1.5	1.6	1.6	1.5	1.5	1.4
	W	0.9	0.9	1.3	1.4	1.5	1.7	1.7	1.8	1.8	1.8	1.7	1.6	1.6
25	Y	1.1	1.2	1.3	1.5	1.5	1.5	1.6	1.6	1.7	1.6	1.5	1.5	1.4
	W	0.8	0.8	0.8	0.9	0.9	0.9	1.1	1.4	1.6	1.6	1.6	1.5	1.5

Table 3.3: Average Width (cm) of Zea mays leaves grown on soil contaminated with different concentrations of petroleum sludge

C. RESULT OF LABORATORY ANALYSES

Before planting, the heavy metal and total petroleum hydrocarbon (TPH) content of the sludge and soil samples were analyzed in order to determine the effect of the maize plant on these parameters after the experiment. In Figure 1, the sludge sample showed very high TPH and Lead contents while the least heavy metal content was Cadmium (2.2mg/l). In figure 2, the uncontaminated soil had some heavy metals but in minute quantities compared to that of sludge, but no TPH.

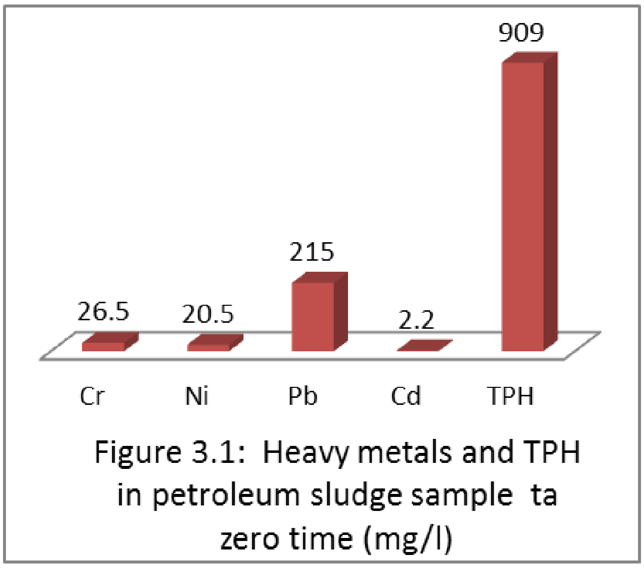

Figure 3.1

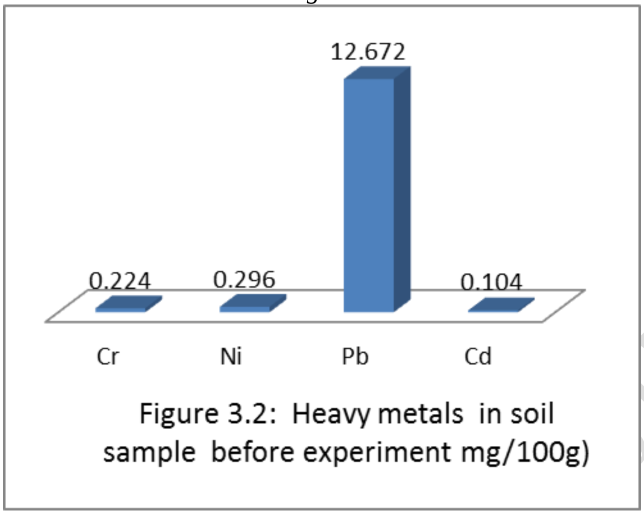

Figure 3.2

The laboratory analyses of the various sludge contaminations showed significant decrease in the heavy metals and TPH content of the beds. Figure 9, shows result of laboratory analysis of the unused petroleum sludge sample after the duration of the experiment indicating decrease in the heavy metals and TPH. Lead and TPH contents for example reduced from 215mg/l to 212mg/l and 909mg/l to 891mg/l respectively.

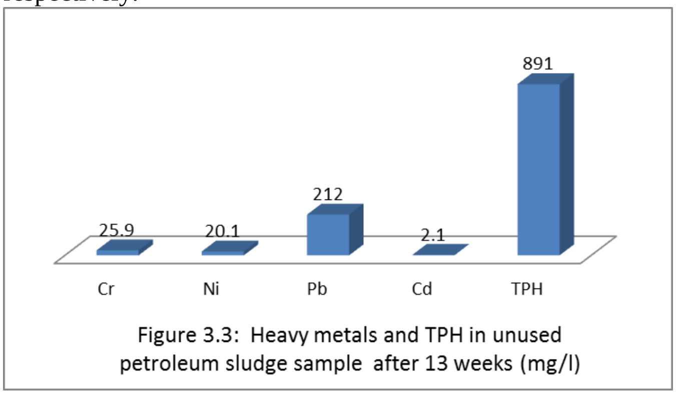

Figure 3.3

a. *HEAVY METAL AND TPH CONTENT OF EACH BED BEFORE AND AFTER PLANTING*

Table 4a shows the heavy metals and TPH contents of each bed before planting which was calculated by adding the heavy metal and TPH content of the respective percentages of soil and sludge ratios. TPH had higest value of 227.25g/100g in bed with 25% sludge. Among all the heavy metals analyzed, Lead had the highest value in bed with 25% sludge. The level of TPH bioaccumulated by maize plant increased as the values increased in the beds. The same was also observed in heavy metals bioaccumulation. These values (Table 4c) were calculated by subtracting the obtained values in Table 4b from values in Table 4a.

	0% Sludge	5% Sludge	10% Sludge	15% Sludge	20% Sludge	25% Sludge
Chromium	0.224	1.538	2.852	4.165	5.479	6.793
Nickel	0.296	1.306	2.316	3.327	4.337	5.347
Lead	12.67	22.79	32.903	43.02	53.136	63.253
Cadmium	0.104	0.209	0.314	0.418	0.523	0.625
TPH	-	45.45	90.9	136.35	181.8	227.25

Table 3.4b: Heavy Metal & TPH Concentrations of Each Bed after 13 Weeks of Planting (Mg/100g)

	0% Sludge	5% Sludge	10% Sludge	15% Sludge	20% Sludge	25% Sludge
Chromium	0.202	1.511	0.480	1.120	2.368	3.344
Nickel	0.224	0.908	0.232	0.336	0.400	0.496
Lead	11.136	16.424	13.416	11.920	12.344	13.008
Cadmium	0.032	0.048	0.024	0.088	0.096	0.112
THP	-	0.440	0.300	1.840	6.300	12.560

Table 3.4a: Heavy Metal & TPH Concentrations of Each Bed before Planting (Mg/100g)

	0% Sludge	5% Sludge	10% Sludge	15% Sludge	20% Sludge	25% Sludge
Chromium	0.022	0.027	2.372	3.045	3.111	3.449
Nickel	0.072	0.398	2.084	2.991	3.937	4.851
Lead	1.534	6.366	19.487	31.100	40.792	50.245
Cadmium	0.072	0.161	0.290	0.330	0.427	0.513
THP	-	45.010	90.600	134.510	175.500	214.690

Table 3.4c: Heavy Metal & TPH Concentrations absorbed by Zea mays Plants After 13 Weeks (Mg/100g) (Values in Table 4a – Values in Table 4b)

SOIL-PLANT TRANSFER FACTOR OR BIOACCUMULATION FACTOR OF *ZEA MAYS* FOR THE HEAVY METALS

Soil-plant transfer factor or bioaccumulation factor, f, is expressed as the ratio of plant metal concentration after the experiment, a, divided by the total metal concentration in soil before the experiment, b. Expressed mathematically as: $f = a/b$

The heavy metal concentration and TPH of the contaminated soil with plants after the experiment was subtracted from heavy metal and TPH concentration of the raw sludge without plants after the experiment to give the actual heavy metal and hydrocarbon uptake of the maize plant.

	5% SLUDGE	10% SLUDGE	15% SLUDGE	20% SLUDGE	25% SLUDGE
Chromium	0.018	0.832	0.731	0.568	0.508
Nickel	0.305	0.900	0.900	0.713	0.907
Lead	0.279	0.592	0.723	0.768	0.794
Cadmium	0.770	0.924	0.789	0.816	0.821
TPH	0.990	0.997	0.987	0.965	0.945

Table 3.5: Bioaccumulation factor (f) of Zea mays for heavy metals & TPH

D. STATISTICAL ANALYSIS

Comparison of the performance of maize plants in 0%, 5%, 10%, 15%, 20% and 25% sludge contaminations as regards to some physical parameters as shown in Tables 4.5 and 4.6.

ANOVA summary for the performance of maize in soil contaminated with different concentrations of petroleum (oily) sludge.

TEST FOR HYPOTHESIS 2: Different concentrations of petroleum (oily) sludge have no significant effect on the physical performance of *Zea mays* considering the following parameters: stem length, Height and leaf width

MAIZE ONE: YELLOW MAIZE

Table 6 below statistically summarized the effect of the petroleum sludge contamination on the physical parameters of the yellow maize plant. The null hypothesis was rejected since the F_{cal} (28.658) was greater than the F_{tab} (4.370) at P = 0.05 and df = 5.

Source	Type III Sum of Squares	df	Mean Square	F
Model	328291.306[a]	9	36476.812	222.707
Sludge	23469.422	5	4693.884	28.658
Gparameters	101209.158	3	33736.386	205.975
Error	49300.394	301	163.789	
Total	377591.700	310		

Table 3.6: ANOVA I

Decision: Since $F_{cal} > F_{tab}$, we reject the Null hypothesis, thus, the sludge had significant effect on the physical parameters of the yellow maize plant.

MAIZE TWO: WHITE MAIZE

Source	Type III Sum of Squares	df	Mean Square	F
Model	262593.581[a]	9	29177.065	319.524
Sludge	12799.382	5	2559.876	28.034
Gparameters	83829.467	3	27943.156	306.012
Error	27485.519	301	91.314	
Total	290079.100	310		

Table 3.7: ANOVA II

Decision: Since $F_{cal} > F_{tab}$, we reject the Null hypothesis and accept the alternate, implying that sludge concentration has significant effect on the physical parameters of the white maize plant.

IV. DISCUSSION AND CONCLUSION

A. DISCUSSION

Maize plant is best raised in hotbed in early spring, but can germinate in ordinary soil in May (IKISAN, 2000). Germination can be impeded due to non-penetration of water oxygen into the soil due to the characteristic nature of the contaminant (oily sludge) (Yang, 2009; Al-Mutaira, 2008; Kravola, 2011). Germination of the maize planted on the contaminated soil may also have been inhibited by the toxic nature of the petroleum sludge as it can lead to soil morphological changes (Robertson, 2007), create nutient deficiency (Al-Mutaira, 2008). Furthermore, high heavy metal content of the petroleum sludge is known to adversely affect seed germination. For instance, Nickel (Ni) is reported to be toxic to most plant species affecting amylase, protease and ribonuclease enzyme activities, thus retarding seed germination and growth of many crops (Ahmad and Ashraf, 2011). Lead (Pb) has been reported to strongly affect the seed morphology and physiology, thus inhibiting germination, root elongation, seedling development and plant growth (Pourrut, *et al.*, 2011). Cadmium (Cd) has been shown to cause delay in germination, induce membrane damage, impair food reserve mobilization by increased cotyledon/embryo ratios of total soluble sugars, glucose, fructose and amino acids leading to nutrient loss (Rahoui, *et al.*, 2010). The synergistic effect of these heavy metals and others in the petroleum (oily) sludge may have possibly affected the maize seed germination negatively.

The toxic nature of the petroleum sludge may have further affected the general performance of the germinated maize plants with respect to heights and average width of the leaves. Considering the fact that petroluem sludge creates nutrient deficiencies (Al-Mutaira, 2008), the basic nutrient requirements of maize plant such as Nitrogen, Potassium, Phophorus, Zinc and Molybdenum, may have been affected, thus discoloraton, stunted growth, withering of leaf tips and edges, etc, observed in some maize plants during the course of this study.

The bioaccumulation factor, f of maize plant was highest for total petroleum hydrocarbon (0.965 – 0.997). In as much as its value for heavy metals was high too, it was lower than the values recorded by Mathe-gaspar and Anton (2005) for Cd (3.33). Maize plant has been known to accumulate Cd (Kimenyu *et al.*, 2009) and Pb (Pereira *et al.*, 2007) above levels that define metal hyperaccumulation. There was general variation in the bioaccumulation factor of maize plant in this study. Some of the contributory factors include among others, initial level of respective heavy metals in the contaminated soil, and duration of the planting period. The highest metal accumulation is possibly achieved within a short period of 21 – 30days (Peciulyte *et al.*, 2009); leaving a maize plant on a contaminated soil lowers the f-value due to increase in plant biomass, leading to distribution of metals over the whole plant (Kimenyu *et al.*, 2009). These assertion above may have contributed to the results obtained.

B. CONCLUSION

Growth of *Zea mays* plants in a petroleum-contaminated soil is limited. Higher concentration of petroleum sludge impede germination of maize and possibly other cereals and plants in the same family. Maize plant basically bioaccumulates petroleum hydrocarbons as well as heavy metals with high bioaccumulation factor, f, thus can be used to phytoremedy environment polluted with related petroleum compounds.

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