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Phytoremediation of Spent Oil and Palm Kernel Sludge Contaminated Soil Using Sunflower (*Helianthus annuus*) L

[*1]ODEBODE, AJ; [2]NJOKU, KL; [2]ADESUYI, AA; [2]AKINOLA, MO

[*1]*Department of Botany, University of Lagos, Akoka, Lagos, Nigeria*
[2]*Environmental Biology Research Unit, Cell Biology and Genetics Department, University of Lagos, Akoka, Lagos, Nigeria*
**Corresponding Author Email: odebode04@yahoo.co.uk; Other Authors Email: kecynjoku@gmail.com; biologistalex@gmail.com; mayomi12@yahoo.com*

ABSTRACT: This study was carried out to investigate the phytotoxicity of spent engine oil and palm kernel sludge on seed germination, seedling early growth and survival of sunflower (*Helianthus annuus* L) and its phytoremediating potential. 8.0 kg topsoil mixed with 2, 4, 6, 8 and 10% (w/v) of spent engine oil and palm kernel sludge, while the control was not mixed with spent oil and sludge (0%). The seeds were sown on these soils and monitored daily. Parameters taken were; plant height, leaf number and stem girth. The result showed that spent engine oil treated plants adversely affected growth compared to palm kernel sludge plants and control which performed better. For plant height, the mean stem girth for control at 2nd week was 0.40±0.05 mm, spent engine oil was 5.96±0.97 palm kernel oil effluent was 14.73±1.16 and at 12th week, control was 1.30±0.05 while for SEO the plant had withered and 124.6±9.02 for POE. Number of leaves at the 12th week was 26.00±2.08 in the control, 8.66±0.66, for spent engine oil at 4%, while for palm oil effluent it was 27.66±0.66, at 4%, concentration respectively. Stem girth at 2 weeks for spent engine oil was 0.19±0.05 at 2%, 0.43±0.03 for palm kernel oil effluent and at the 12th week of planting at 10% concentration was 1.63±0.08 for palm kernel oil effluent, and all plants had withered off for spent engine oil at same concentration at the 12th week. Also, spent engine oil at all concentrations delayed the germination of *Helianthus annuus* by 2days compared to control. Comparison analysis test showed that growth in untreated plants were significantly higher ($p>0.05$) than spent oil and palm kernel sludge treated plants. Similar result was observed for leaf number and stem girth which had higher mean value in palm kernel sludge and control compared to spent oil. Sunflower grown in 8% and 10% palm kernel sludge contaminated soil also flowered eight days earlier than control plants, while spent oil treated plant did not. The result shows that sunflower cannot tolerate high (4%, 6%, 8% and 10%) concentrations of spent engine oil in soil compared to palm oil effluent. Therefore, spent engine oil should be properly disposed because of its adverse effect on the growth and yield of sunflower

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Soil pollution due to spent engine oil has become a global environmental concern that pose a threat to human health if the heavy metals and highly toxic polycyclic aromatic hydrocarbons constituents enter the food chain (Ghosh and Singh, 2005; Vwioko and Fashemi, 2005). Hallier-Soulier *et al.* (1999) stated that usefulness of petroleum products in the world economy has created a platform for the distribution of large amount of toxins into populated areas and ecosystems. Pollution from spent oil is more widely spread than crude oil especially in urban centres where there are automobiles and generators using petroleum products (Odjegba and Sadiq, 2002). Spent oil in Nigeria has been persistently hazardous due to indiscriminate disposal by automobiles mechanics either in gutters, water drains, roadsides or open lands (Agbogidi, 2011). High amounts of heavy metals such as Vanadium, Nickel, Lead and Iron in spent oil polluted soils may contain some toxic materials that could affect growth and yield of plants (Njoku *et al.*, 2008; Anoliefo and Vwioko, 2001). Spent engine oil in soil creates negative impacts on life due to poor aeration as a result of soil immobilization of soil nutrients and lowering of soil pH (Nwoko *et al*., 2007). Palm oil mill effluent is one of the most highly pollutant effluent from agro-industrial residues due to its high organic load and it causes depletion of dissolved oxygen when discharged into the environment untreated (Agi, 1980; Blamey and Chapman, 1981; Ritchie and Ne Smith;1991; Lorestani, 2006). When soil is polluted, the enzyme activity and the physiochemical properties are negatively affected by effluent discharges, plants, man and other animals that depend directly and indirectly on it are also adversely affected (Zakaria *et al*., 2002). Therefore, the challenge of converting palm oil mill effluent to environmental friendly waste requires effective disposal technique. Sunflower (*Helianthus* *annus* L.) belongs to the family Asteraceae, and is an agronomic crop widely cultivated throughout the world because of their relatively short growing season (Soriano *et al*., 2004; Groove *et al.*, 2005). Typically, domesticated sunflowers usually have a single stalk topped by a large flower and are significantly different from the smaller, multiply branched wild sunflower. During the growing season, the individual flowers are each pollinated (Thakuria *et al*., 2004). The use of higher plants (phytoremediation), fungi (mycoremediation) and bacteria in cleaning up pollutants have been found useful since two decades ago. This study therefore aimed at evaluating the suitability and response of *Helianthus annuus* to phytoremediation of spent oil and palm kernel sludge polluted soil.

MATERIALS AND METHOD

The research work was carried out in the screen house at the Department of Cell Biology and Genetics, University of Lagos, Akoka, Lagos. The spent engine oil used was obtained from two different auto-mechanic workshops in Mushin, Lagos state. The Palm kernel sludge was obtained from Palm Oil Mill Industry, Agbowo, Ibadan, Oyo state, Nigeria. The seeds of Sunflower seeds (Gombe local) were obtained from the Seed Technology Division of National Horticultural Research Institute (NIHORT), Ibadan, Nigeria.

Soil Preparation, contamination and Sowing: Top soil (0-15cm) depth was obtained from the Botanical Garden of the University of Lagos. The soil was air-dried, gently crushed and sieved in a 2mm mesh to remove gravel and debris. In each pot, 8 kg soil was used to fill 36 pots making triplicates for each concentration of contaminants and control. The pots were irrigated with 2%, 4%, 6%, 8% and 10% v/w of spent engine oil and oil mill sludge separately in triplicates. Contaminants were thoroughly mixed in order to obtain a homogenous soil/pollutant mixture. Five viable seeds of *Helianthus annuus* L (Gombe local) were sown to each pot.

Soil contamination: Spent oil was gradually added on to the soil samples and mixed thoroughly in order to obtain a homogenous soil/pollutant mixture. Same was done with palm kernel sludge effluent. The soil was treated with both pollutants to achieve 2%, 4%, 6%, 8% and 10% v/w. The mixing was gradually done to ensure thorough and even mixing. The control was without spent oil and sludge.

Plant growth measurement: Growth parameters were monitored and measurements were carried out on the following parameters: Leaf number, plant height and stem girth. The height of each plant was measured at regular interval with a metre rule from the soil level to the terminal bud. The stem girths were taken 2cm above the soil level with a Vernier caliper. The number of leaves was also counted.

Physicochemical analysis of soil: The physicochemical properties of soil samples collected were determined for the following parameters; Soil pH, soil moisture content, total organic matter (TOM), phosphorus (P), total nitrogen (TN), heavy metals (HM), and total petroleum hydrocarbon content (TPH).

Determination of Soil pH was carried out according to the method described by Brady and Weil, (1990). 50g already air dried soil sample was oven dried at 110ºC for 48 hrs to determine the soil moisture content. Percentage estimation of the soil moisture was then carried out as was in line with the procedure of Association of Analytical Chemists (A.O.A.C., 2003);

$$\%\ \mathrm{MC} = \frac{\text{wt of soil before oven drying}}{\text{wt of oven dried soil}}\ \mathrm{x}\ 100\%$$

Where MC = moisture content

Determination of Total organic matter (TOM), Phosporus (P), and Total Nitrogen (TN) were also carried out according to the method described by Association of Analytical Chemists (A.O.A.C., 2003).

Fifty grams of soil sample was transferred into a round bottom flask containing 200ml methanol and 8grams of Potassium hydroxide (KOH), and reflux for 2 hours. After cooling, the mixture was filtered into a separatory funnel, 30ml of n-hexane was added to the round bottom flask and the flask rotated to rinse the sides. The solvent was then transferred to the separatory funnel and the extract was vigorously shaken for 2minutes. Layers were allowed to separate.

The n-hexane layer was filtered through a funnel containing n-hexane moistened filter paper into a 250ml beaker. The step was repeated twice with 30ml portion of fresh n-hexane directly added to the separatory funnel, combining all n-hexane into the beaker. The tip of the separatory funnel, filter paper and the funnel were then rinsed with a total of 5-10 ml n-hexane and collected the rinsing in the beaker.

The extract was reduced to 5ml using a rotary evaporator. 5ml of the concentrated extract was eluded through a column that had been packed with silica gel. The elute was then collected using a tarred flask and the n-hexane was subsequently recovered using the rotary evaporator (Cincinapi, 1983).

$$\text{TPH ug/g} = \frac{\text{wt of TPH in tarred flask}}{\text{Wt of sample}} \times 1000$$

Statistical analyses: Statistical analyses were done using the graph pad prism, version 6.0 using a two way analysis of variance followed by Tukey-Kramer multiple comparison tests.

RESULTS AND DISCUSSION

Effect of spent engine oil and palm oil effluent on plant height of Helianthus annuus: The effect of spent engine oil and palm oil effluent contamination on plant height of *Helianthus annuus* is shown in table 1. The result obtained showed a better growth performance in *Helianthus annuus* grown in control setup and palm oil mill effluent contaminated soil than in spent engine oil contaminated. There was significant difference between the plant height in control and 2%, 4%, 6%, 8% and 10% concentrations spent oil ($p<0.05$) while no significant difference between the various concentrations of palm oil effluent contaminants ($p>0.05$) after 12 weeks of growth. There was complete growth inhibition of *Helianthus annuus* in 10% spent engine oil contamination showing that the average plant height decreased significantly with an increase in the concentrations of spent engine oil.

Table 1: Effect of spent engine oil (SEO) and palm oil effluent (POE) on plant height (cm) of *Helianthus annuus*

Week	Control	2%		4%		6%		8%		10%	
		SEO	**POE**	**SEO**	**POE**	**SEO**	**POE**	**SEO**	**POE**	**SEO**	**POE**
2	13.43 ±1.28	10.16 ±2.50	15.76 ±1.13	10.06 ±1.04	14.03 ±0.90	7.66 ±0.88	15.20 ±0.35	7.90 ±1.65	14.23 ±0.04	5.96 ±0.97	14.73 ±1.16
4	40.33 ±3.50	10.93 ±0.78	33.26 ±2.90	18.66 ±1.11	32.66 ±4.45	14.33 ±2.22	29.33 ±8.76	12.66 ±3.00	27.66 ±0.59	10.66 ±0.05	28.33 ±2.54
6	57.66 ±2.38	19.00 ±5.50	53.66 ±5.40	22.66 ±1.89	39.00 ±2.92	16.00 ±1.15	40.00 ±0.57	15.00 ±1.96	42.33 ±1.58	14.00 ±1.16	41.00 ±0.99
8	74.00 ±1.50	19.88 ±1.05	71.00 ±1.08	30.66 ±2.56	67.33 ±7.63	22.00 ±0.06	68.33 ±2.96	22.66 ±3.63	69.66 ±3.20	20.66 ±1.24	78.66 ±3.65
10	109.33 ±8.17	21.33 ±0.59	100.00 ±7.00	23.66 ±3.20	94.66 ±4.66	23.00 ±0.92	96.00 ±23.45	21.33 ±0.59	98.66 ±8.25	21.66 ±0.89	95.66 ±4.44
12	130.33 ±0.05	22.00 ±1.21	123.33 ±8.90	27.33 ±2.20	124.33 ±15.67	26.66 ±1.23	121.00 ±5.48	21.00 ±0.50	121.66 ±5.69	wo	124.6± 9.02

Values show mean ± standard error of 3 replicates. wo - withered off

Effect of spent oil and palm oil effluent on stem girth (mm) of Helianthus annus: The effect of spent engine oil and palm oil mill effluent on stem girth (mm) of *Helianthus annus* is presented in Table 2. The mean stem girth for control at 2nd week was 0.40±0.05 mm and at 12th week was 1.30±0.05, and this was significantly higher compared to that obtained from soil contaminated with spent engine oil. The average stem girth of *Helianthus annus* obtained from control and palm kernel sludge were quite similar with no significant difference for all the treatments. Mean stem girth *H. annus* grown in soil polluted with 6%, 8% and 10% spent engine was adversely affected, this might be attributed to the fact that the contaminant at this level is phytotoxic.

Table 2: Effect of spent engine oil (SEO) and palm oil effluent (POE) on stem girth (mm) of *Helianthus annus*

Week	Control	2%		4%		6%		8%		10%	
		SEO	**POE**	**SEO**	**POE**	**SEO**	**POE**	**SEO**	**POE**	**SEO**	**POE**
2	0.40 ±0.05	0.19 ±0.00	0.43 ±0.03	0.21 ±0.02	0.40 ±0.05	0.21 ±0.01	0.43 ±0.03	0.20 ±0.00	0.36 ±0.03	0.20 ±0.50	0.36 ±0.08
4	0.80 ±0.05	0.27 ±0.07	0.93 ±0.03	0.21 ±0.01	1.03 ±0.13	0.22 ±0.01	1.30 ±0.00	0.20 ±0.02	1.13 ±0.03	0.37 ±0.03	1.06 ±0.03
6	0.96 ±0.03	0.25 ±0.03	1.16 ±0.03	0.27 ±0.03	1.33 ±0.03	0.27 ±0.06	1.36 ±0.01	0.29 ±0.01	1.23 ±0.01	0.31 ±0.04	1.18 ±0.08
8	1.10 ±0.05	0.20 ±0.00	1.17 ±0.03	0.21 ±0.04	1.41 ±0.04	0.21 ±0.00	1.48 ±0.01	0.20 ±0.00	1.33 ±0.03	0.20 ±0.00	1.40 ±0.00
10	1.16 ±0.03	0.36 ±0.08	1.21 ±0.01	0.26 ±0.04	1.43 ±0.04	0.21 ±0.01	1.42 ±0.01	0.20 ±0.01	1.38 ±0.01	0.20 ±0.00	1.46 ±0.03
12	1.30 ±0.05	0.40 ±0.00	1.25 ±0.02	0.26 ±0.02	1.45 ±0.02	0.28 ±0.06	1.45 ±0.02	0.21 ±0.02	1.46 ±0.03	wo	1.63 ±0.08

Values show mean ± standard error of 3 replicates. wo - withered off

Effect of spent oil and palm oil effluent on number of leaves of Helianthus annuss: The leaf numbers of sunflower plants exposed to different levels of spent oil and palm oil effluent pollution is shown in table 3. The leaf numbers *Helianthus annuss* were highly reduced in the spent engine oil contaminated soil at

2%, 4%, 6%, 8% and 10% spent oil when compared to that grown in control and palm oil effluent contaminated soil. After two weeks of planting, the leaves number of *Helianthus annuss* in the control setup had a mean value of 10.33±0.33 which increased to 26.00±2.08 at the end of 12th week. For sunflower grown in spent engine oil after 2 weeks it was 4.00±0.00, 4.66±0.66, 4.00±0.00, 4.20±0.10 and 4.00±0.00 in 2%, 4%, 6%, 8% and 10% concentration respectively, while for those in palm oil effluent it was 8.33±0.33, 7.66±0.33, 8.66±0.50, 8.33±0.33 and 8.00±0.00 in 2%, 4%, 6%, 8% and 10% concentration respectively. At 12th week the leaves number of *Helianthus annuss* was 26.00±2.08 in the control, 7.33±0.66, 8.66±0.66, 6.33±0.88, 6.00±0.00 for spent engine oil at 2%, 4%, 6% and 8% respectively while for palm oil effluent it was 26.00±0.00, 27.66±0.66, 26.66±0.66, 25.33±0.66 and 27.66±0.33 at 2%, 4%, 6%, 8% and 10% concentration respectively. There was high significant difference between the leaf number of the control and 2%,4%,6%,8% and 10% concentrations ($p<0.001$) plants for spent oil contaminated plant but no significant difference was observed in leaf number of palm oil effluent at $p>0.05$ for all treatments.

Table 3: Effect of spent engine oil (SEO) and palm oil effluent (POE) on number of leaves of *Helianthus annuss*

Week	Control	2%		4%		6%		8%		10%	
		SEO	POE	SEO	POE	SEO	POE	SEO	POE	SEO	POE
2	10.33 ±0.33	4.00 ±0.00	8.33 ±0.33	4.66 ±0.66	7.66 ±0.33	4.00 ±0.00	8.66 ±0.50	4.20 ±0.10	8.33 ±0.33	4.00 ±0.00	8.00 ±0.00
4	12.33 ±0.33	4.66 ±0.66	13.33 ±0.66	4.66 ±0.66	12.33 ±2.18	4.66 ±0.66	10.66 ±0.66	4.66 ±0.66	11.33 ±0.66	4.00 ±0.00	10.66 ±0.66
6	16.66 ±0.88	5.33 ±0.66	14.66 ±0.66	4.66 ±0.66	13.00 ±1.52	4.66 ±0.66	14.33 ±0.88	5.33 ±0.66	14.00 ±0.00	5.00 ±0.66	13.33 ±0.66
8	19.66 ±1.66	6.06 ±0.56	21.00 ±2.64	5.33 ±0.66	21.00 ±2.00	5.33 ±0.66	21.00 ±2.00	6.00 ±0.00	21.00 ±1.52	5.30 ±0.66	22.66 ±0.88
10	20.00 ±0.57	6.66 ±0.66	25.66 ±1.20	7.33 ±1.20	24.66 ±0.66	6.00 ±1.15	22.33 ±0.88	6.00 ±0.00	23.33 ±0.66	5.30 ±0.66	25.00 ±1.00
12	26.00 ±2.08	7.33 ±0.66	26.00 ±0.00	8.66 ±0.66	27.66 ±0.66	6.33 ±0.88	26.66 ±0.66	6.00 ±0.00	25.33 ±0.66	wo	27.66 ±0.33

Values show mean ± standard error of 3 replicates. Wo-withered off

Effects of spent engine oil (SEO) and palm oil effluent (POE) on soil physicochemical properties: pH: The pH of the soils exposed to different concentrations of spent engine oil and palm oil effluents before and after planting *Helianthus annuss* is shown in figure 1. The pH of the soil was generally higher at the beginning of the study than at the end for both SEO and POE at the different concentrations. There was a gradual decrease in the pH of the soil for 2% palm oil effluent concentration with mean value from 7.95±0.02 before planting to 6.50±0.16 after planting while same concentration of spent oil reduced from7.90±0.11 to 6.90±0.05 after planting. The mean value at 8% palm kernel sludge also decreased from 8.03±0.08 to 6.64±0.04 likewise for spent oil at same concentration reduced from 8.06±0.08 to 7.10±0.01 after planting. There was no significant difference ($p>0.05$) in the initial pH for all the concentration of POE and SEO before planting, however, significant difference was observed ($p<0.05$) after planting of *Helianthus annuss* for all concentration of palm kernel sludge and spent engine oil. The availability of nutrients in the soil is greatly affected by the pH.

Total Organic Matter: The Total Organic Matter of the soil exposed to different concentrations of spent oil and palm kernel sludge before and after growth of *Helianthus annuus* is shown in figure 2. The total organic matter of the soil was generally higher at the beginning of the study than at the end for both contaminants and all treatments. Palm kernel sludge at 2% concentration before planting had mean value was 6.76±0.28% but reduced to 5.16±0.08% after growth of plant, likewise spent oil at 2% concentration had a reduction from 4.73±0.12% to 4.36±0.14%. The mean values of total organic matter obtained for palm kernel sludge at 10% concentration also showed a reduction from 8.26±0.27% to 7.63±0.20% while spent oil at 10% concentration reduced from 6.00±0.11% to 3.70±0.60% after growth of plant. There was however no significance difference at ($p>0.05$) between all concentrations of spent oil and palm kernel sludge at the beginning and at the end of the study.

Phosphorus: The phosphorous level of the soil exposed to different concentrations of palm kernel sludge and spent oil is shown in figure 3. The phosphorous content of soil was generally higher at the beginning of the study than at the end. 2% concentration palm kernel sludge at the beginning had mean value of 1.88±0.04mg/kg but reduced to 0.07±0.09mg/kg after growth of plant while spent oil had mean value of 2.13±0.08mg/kg before planting and 1.19±0.05mg/kg after planting. The phosphorous content of the soil samples at 2% palm kernel sludge was significantly different ($p<0.0001$) from 6%, 8% and 10% spent oil concentrations before planting.

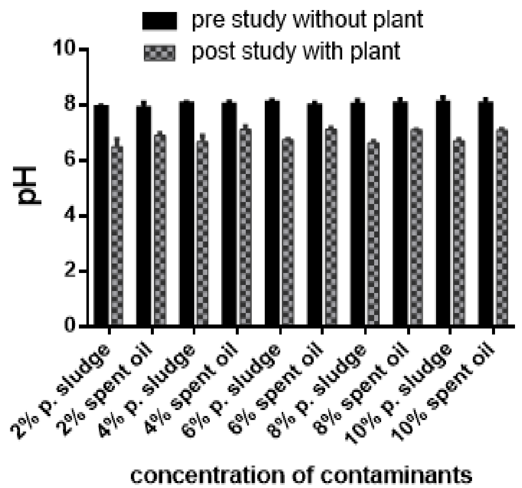

Fig 1: Effect of palm kernel sludge and spent oil on pH of polluted soil. Values show mean ±standard error of 3 replicates

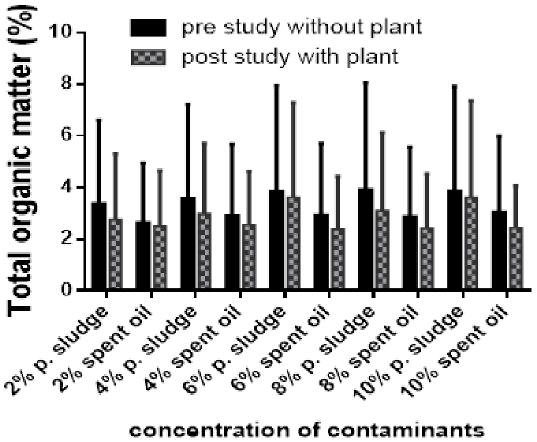

Fig 2: Effect of palm kernel sludge and spent oil on Total Organic Matter content (Values show mean ± standard error of 3 replicates)

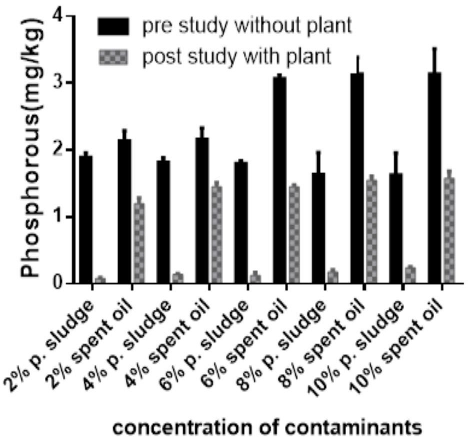

Fig 3: Effect of palm kernel sludge and spent oil on phosphorous content of soils (Values show mean ± standard error of 3 replicates)

Also, at 2% and 4% spent oil concentrations there was significant difference ($p<0.001$) from palm kernel sludge after planting. Phosphorous content was higher in soil before planting but reduced at the end of the plant growth.

Nitrogen: The nitrogen content of the soil exposed to different concentrations of palm kernel sludge and spent oil before planting and after planting is shown in figure 4. The nitrogen content of all concentrations of both contaminants was generally higher before planting than after the growth of the plant. The mean value of palm kernel sludge at 2% concentration decreased from 0.26±0.01mg/kg to 0.23±0.01mg/kg while for the same concentration in spent oil, it reduced from 0.27±0.01mg/kg to 0.19±0.01mg/kg. Palm kernel sludge at 10% concentration before planting had mean value of 0.47±0.03mg/kg but also reduced to 0.39±0.01mg/kg while spent oil at same concentration also reduced from 0.30±0.02mg/kg before planting to 0.19±0.19mg/kg after growth of plant. There was no significance difference ($p<0.05$) between spent engine oil and palm kernel sludge for all the different treatments except at 4% concentration ($p>0.05$). However, there was also significant difference at $p<0.001$ between 10% spent oil and 10% palm kernel sludge contamination.

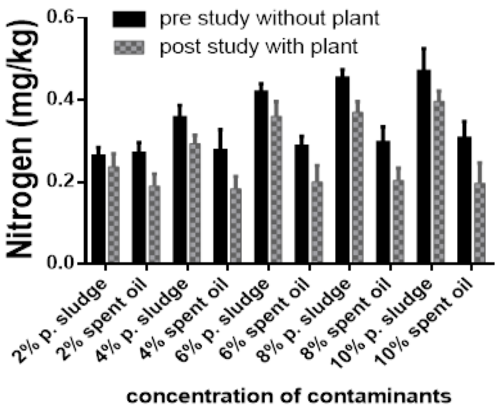

Fig 4: Effect of palm kernel sludge and spent oil on nitrogen content (Values show mean ± standard error of 3 replicates)

Potassium: The potassium content of the soil exposed to different concentrations of palm kernel sludge and spent oil when compared before and after planting is shown in figure 5. The potassium content increased at all concentrations of spent oil at the end of the study than at the beginning while there was a gradual reduction in potassium content in all concentrations of palm kernel sludge at the end of planting than at the beginning. 2% palm kernel concentration had mean value reduced from 0.15±0.03mg/kg to 0.09±0.12mg/kg while an increase was observed in mean of 2% spent oil concentration from

0.07±0.02mg/kg to 0.11±0.01mg/kg. For 10% palm kernel concentration, the mean value decreased from 0.26±0.02mg/kg before planting to 0.12±0.00mg/kg after planting while increase in mean value was observed from 0.21±0.01mg/kg before planting to 0.37±0.00mg/kg after planting for 10% spent oil concentration. There was however no significant difference after planting at p<0.05 between 2% palm kernel sludge with 2% spent oil while significance was observed at p<0.0001 between 2% spent oil and 8% and 10% spent oil concentrations after plant growth. Also, significance difference was observed at p<0.00001 after planting between 10% palm kernel sludge and 10% spent oil concentrations. In this study, a reduction in nutrient content (Total organic matter, phosphorous and potassium) pH and moisture content of both contaminated soils after planting was observed except for nitrogen in spent oil contaminated soil. This is similar to the findings of Adenipekun and Fasidi, (2005) in crude oil and engine oil polluted soil where higher organic carbon, nitrogen and phosphorous was reported compared to the control samples.

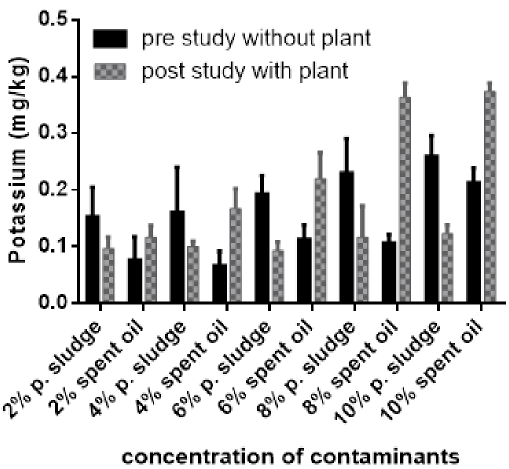

Fig 5: Effect of palm kernel sludge and spent oil on potassium level (Values show mean ± standard error of 3 replicates)

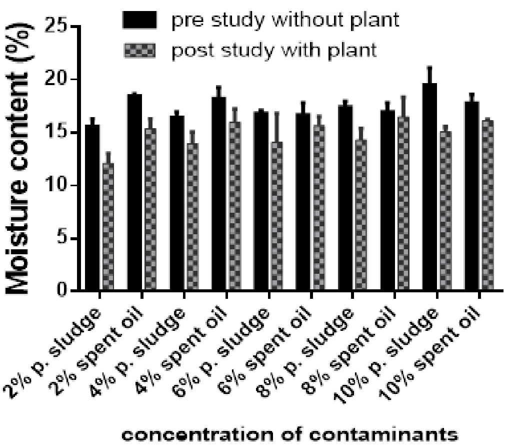

Fig 6: Effect of palm kernel sludge and spent oil on moisture content of soils (Values show mean ± standard error of 3 replicates).

Moisture content: The moisture content of soil exposed to different levels of palm kernel sludge and spent oil contamination is shown in figure 6. 2% palm kernel sludge contamination had mean value decreased from 15.56±0.41% to 12.10±0.55% while at same concentration for spent oil the mean value also reduced from 18.46±0.12% to 15.39±0.53%. Also, at 10% palm kernel sludge concentration, there was a mean value reduction from 19.48±0.95% to 15.10±0.25% while for spent oil at same concentration, mean reduction was from 17.76±0.49% to 16.09±0.08%. Moisture content was observed to decrease in all concentrations for both pollutants after plant growth compared to before planting.

Total petroleum hydrocarbon: The total hydrocarbon content of the soil exposed to different concentrations of spent oil before and after plant growth is shown in figure 7. The initial TPH level of the soil was generally higher when compared with the final level after the growth of *Helianthus annuus*. Total Hydrocarbon Content show that at 2% concentration, mean decreased from 2634.6±67 mg/kg to 1031.03±156.04mg/kg after plant growth while at 6%, mean value also decreased from 4853.00±178.02mg/kg to 1522.40±324.64mg/kg. 10% spent oil concentration had mean decrease from 6210.76±438.25mg/kg to 1537.16±281.34mg/kg after plant growth. There was significant difference (p<0.05) between all the different treatment (2% - 10%) of spent oil before planting. Also, significant change was observed between the initial and final concentrations of spent oil after the growth *Helianthus annuus*. Since the soil total petroleum hydrocarbon (TPH) concentration decreased in spent oil contaminated soil although at a less rate, it is believed that processes such as evaporation, direct plant uptake, and adsortion by soil organic matter were resposible for the gradual decrease in TPH content. This suggests that sunflower has limitations to assimilate more TPH into its system for bioaccumulation or for sequestering. Another reason for the low assimilation of Total Petroleum Hydrocarbon by sunflower might be because it possess tap root and reduced microbial activity. Anderson *et al*., (1993) reported that fibrous roots provide a larger surface than tap roots for colonization by soil micro-organisms. This allows a close interaction between the rhizosphere microbial community and the contaminant (Schwab and Banks, 1994). Similarly legumes would do better in remediation of TPH because legumes have a symbiotic relationship with nitrogen-fixing bacteria.

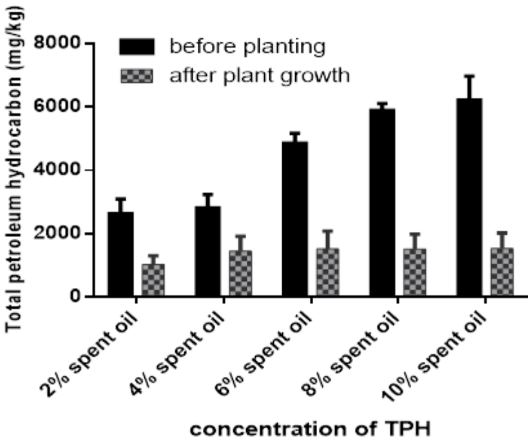

Fig 7: Effect of spent oil on Total hydrocarbon content of soil (Values show mean± standard error of 3 replicates)

The results showed that spent engine oil inhibited plant growth as evidenced by reduction in plant height and the effect was concentration dependents. The reduction in plant height and later death of some of the plants in spent oil contaminated soil could be due to the reduction in nutrient uptake by the plants. Adenipekun *et al*. (2009) reported that the decrease in height of plant with increase in concentration of spent engine oil is probably due to the non-availability of adequate water which possibly affected the nutrient uptake and mobility. The findings are similar to those reported for *Glycine max* by Njoku *et al*. (2008) and Arachis hypogaea by Olayinka and Arinde (2012). Al-Qahtani (2011) also reported significant reduction in plant height and dry matter contents of *Vinca rosea* in soil contaminated with oil refinery sludge when compared with control treatment. The effect of SEO on stem girth is similar to that reported by Olayinka and Arinde (2012) in studies on the effects of spent engine oil on *Arachis hypogaea*. The significant difference observed in this study could be attributed to the fact that crops differed in their responses to pollutants (Adenipekun and Kassim, 2006; Njoku *et al*., 2017).

Generally, the plant grown in palm oil effluent polluted soil had more leaves than the plant grown in spent oil polluted soil. As observed spent engine oil is inhibitory to plant growth and this could be attributed to large amount of hydrocarbons in used oil, including the highly toxic poly aromatic hydrocarbon (PAHs) as reported by Wang *et al*. (2000). Spent engine oil mainly affect plant growth at all concentrations studied because it interferes with factor such as soil aeration, mineral availability, plant water relation and suitable warmth that are suitable for plant growth and development which was not implicated by palm kernel sludge (Olayinka and Arinde, 2012).

Conclusion: This study showed that spent engine oil pollution has adverse effects on Sunflower growth and yield at all concentrations, it has also shown that sunflower plant utilized and reduced the nutrient content of soil contaminated with both palm kernel sludge and spent engine oil. Harnessing the potential inherent in palm kernel sludge as a source of fertilizer should also be worked upon in future research because as shown in this study it gave better performance in terms of sunflower growth and yield compared to the control and spent oil plants. It is therefore suggested that awareness should be raised to educate automobile mechanics on the effect of indiscriminate disposal of petroleum products in the environment. Hence appropriate disposal of spent engine oil should be taken seriously.

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