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Effects of spent engine oil contamination on soybean (Glycine max L. Merril) in an *Ultisol*

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ABSTRACT: An experiment was conducted in the University of Nigeria Nsukka Teaching and Research Farm to determine the effect of spent auto-engine oil on soil and soybean in a Randomized Complete Block Design. Treatments were four levels (0, 1, 2 and 3 %) of spent auto-engine oil (SPO). Top soil samples were collected at 0, 12, 24 and 36 months and analyzed. Results indicated that infiltration rates in plots under 3 % SPO was reduced from 1.40 cm h^{-1} in control plots to the lowest value of 0.07 cm h^{-1} compared to 0.27 cm h^{-1} in 1 % treatment in the first 12 months. Plots contaminated with 3 % SPO gave the lowest K_s values of 6.29, 7.68 and 9.43 cm h^{-1} in the 12th, 24th and 36th months respectively. Data on plant samples showed that 2 % and 3 % SPO contaminations reduced soybean germination from 99 % (control) to 86 and 68 % respectively in the first cropping season whereas 1 % SPO was observed to significantly increase leaf area, dry matter content and grain yield from control values of 52.6 cm^2, 3.01 t ha^{-1} and 0.72 t ha^{-1} to 54.5 cm^2, 4.20 t ha^{-1} and 0.97 t ha^{-1} respectively.

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Keywords: Contamination, soybean, soil physical properties, spent engine oil, *Ultisol*

Nigeria is a major petroleum producing country in the world and the exploration and exploitation of petroleum has brought so much pollution to the Nigerian environment, especially in the Niger delta region of the country. However, in and beyond the Niger delta, pollution incidence emanating from spent engine lubricating oil has been reported to be more widespread and prevalent than that of petroleum (Odjegba and Sadiq, 2002). Lubricating oil is produced by vacuum distillation of petroleum and usually contains chemical additives including amines, phenols, benzenes, calcium, zinc, barium, magnesium, phosphorus, sulphur and lead (Lale *et al*., 2014; Kirk *et. al.,* 2005). It includes mono and multi-grade lubricating oils from petrol and diesel engines, together with gear oils and transmission fluids. Spent auto engine oil is obtained during routine maintenance of automobile and power generating engines; and often indiscriminately disposed into gutters, municipal drainage systems, open vacant plots and farms in Nigeria by auto technicians and allied artisans with workshops on the road sides and open places (Anoliefo and Vwioko, 2005).Various researchers have investigated and reported the ecological toxicity effect of petroleum and spent auto-engine oil. Ahamefule *et al.* (2015) and Agbogidi and Ejemete (2005) noted that oil (petroleum) in soil have deleterious effects on biological, chemical and physical properties of the soil depending on the dose, type of the oil and other factors. Spent auto-engine oil is known to contain increased amounts of heavy metals compared to the unused oil. Okonokhua *et al*. (2007) reported that the proportion and type of these heavy metals present in spent auto-engine oil were dependent on the process generating the waste. These quantitative variations in the chemical properties of spent auto-engine oil and the heterogeneity of soil should expectedly give rise to dissimilarities in research results coupled with the fact that physiological and anatomical differences predispose plants to various degrees of response and response pathways. In this vein, Badrul (2015) reported that oil tends to accumulate in disposal sites in the long-term and may lead to formation of oily scum, which according to Shallu *et al.,* (2014), impedes O_2 and water availability to biota and creates anaerobic conditions in the subsoil, which aids the persistence of the oil. Ashraf (2011) observed that oil-based wastes increased soil hydraulic properties whereas the observation of Ahamefule et *al.* (2014) was the reverse. On the effect of spent engine oil on plant species Agbogidi (2010) reported poorer

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germination response of cowpea with increasing dose of spent engine oil. Vwioko and Fashemi (2005) reported stimulation of germination at 1 % w/w spent engine oil in soil for *Ricinus communis* seedling while germination in higher concentrations (2, 3, 4, 5 and 6 % w/w) exhibited depression. Anoliefo and Edegbai (2000) reported that *Solanum melongena* was more tolerant of spent lubricating oil than *S.incanum*. Similarly Sharifi *et al.* (2007) noted that *Medicago truncatula* was the most tolerant plant species among the six species he examined.

Soybean is one crop that its cultivation is expanding in Nigeria as a result of its nutritive and economic importance and diverse domestic usage, nevertheless, there is however, paucity of information on the response of soybean to spent engine oil contamination in the *Ultisols* of South-eastern Nigeria. Therefore this study was focused on evaluating the effects of spent auto-engine oil on selected soil hydrological properties, growth and yield components of soybean plant.

MATERIALS AND METHODS

Site Description: This study was conducted from 2007 to 2009, on the Teaching and Research Farm of University of Nigeria, Nsukka, located by latitude $06^{0}52'$N and longitude $07^{0}24'$E and at an elevation of 400m above sea level. Mean annual temperature of this location ranges between 26 and 31^{0}C. The average annual precipitation is about 1700mm (FORMECU, 1998) but the area experiences distinct wet (April to October) and dry (November to March) seasons. Rainfall during the wet season is bi-modally distributed, with peaks in July and September and a short dry spell around mid- August.The soil is a reddish brown sandy loam *Ultisol* (Oxic Paleustult) belonging to the Nkpologu series and formed from false bedded sandstone parent materials (Nwadialo, 1989). Ahamefule and Peter (2014) reported that this soil is sandy-loam textured and acid in reaction. Some characteristics of its surface soil are described in Table 1. The site was under natural vegetation fallow, predominantly *Pennisetum purpurem, Mimosa pudica* and *Cynodon dactylon* for about 15years.

Field Methods: Experimental design and layout: The experiment was laid out in a Randomized complete Block Design (RCBD) with four (4) levels of spent auto engine oil contamination replicated three (3) times giving a total of 12 plots. The four (4) levels of spent auto engine oil contamination were 0, 1, 2, and 3 % equivalent to 0, 10, 000, 20,000 and 30,000 mg kg^{-1} of soil respectively. The experiment covered a land area of 15.125 m^2 (5.50 m x 2.75 m)

Field preparations: Soil samples were collected in a grid of 2 x 1 m, bulked and a composite sample taken for laboratory analyses to determine the initial physical and chemical properties of the site. Glyphosate, a post emergence herbicide (a.i ispropylamine) and butachlor, a pre-emergence herbicide (a.i.2-chloro-2, 6- diethyl – N (butoxy methyl) acetanilide) were used to control weeds. The plots were manually tilled and the spent auto engine oil applied two weeks before planting to allow for adequate percolation. The test crop was soybean (*Glycine max L.Merril*), grown from May to August of each year 2007 to 2009. Sowing was done manually at the rate of two seeds per hole, to a depth of 2.5cm and spacing of 50 cm x 25 cm in double rows, and thinned down to one plant per stand after emergence. Each plot contained 20 plants, giving a plant population of 80,000 plants ha^{-1}.

Data Collection: Germination count (GC) was taken 8 days after planting and percent germination calculated thus:

$$GC = \frac{Number\ of\ Germinated\ Seeds}{Number\ of\ Seeds\ Sown} \times 100$$

Whereas leaf area and dry matter content were determined at flowering. Leaf area was determined by an area metre (machine) connected to a monitor which displays the total leaf area and the number of leaves per sample. Dry matter was determined by oven drying plant samples to constant weight and the final weight determined as the dry matter content. Harvesting took place when the soybean pods had sufficiently dried in all treatments. The dry soybean pods were shelled, and the grain weighed at 14 % moisture content to obtain the yield.

Laboratory Studies: Core soil samples were collected from 0 – 20 cm depths at 0 months (before treatment) and 12, 24, 36 months after contamination for determination of saturated hydraulic conductivity (K_s) using the constant head method of Bouwer (1986) and the transposed Darcy's formular for vertical flows of liquid used to calculate K_s thus:

$$\frac{Q}{At} \times \frac{L}{\Delta H}$$

Where:
Q = steady state volume of flow (cm^3)

A = cross sectional area of core sample (cm^2)
t = time elapsed (h)
L = Length of core sample (cm)
ΔH = change in hydraulic head (cm)
Infiltration rate was determined using the double ring infiltrometer method. Total hydrocarbon content of the contaminated soils was determined gravimetrically by toluene extraction (cold extraction) method as described by Odu et al. (1989).

Data analysis: All data collected were subjected to analysis of variance using SPSS version 16.0 computer statistical package while significant treatment means were separated at 5 % probability level with Duncan's New Multiple Range Test.

RESULTS AND DISCUSSION

Initial soil properties of the experimental site: Initial characteristics of the top soil of the experimental site (Table 1) revealed that the texture of the experimental site was sandy-loam whereas the organic carbon content, pH, P, and CEC were generally low to very low. This is typical of degraded tropical soils.

Table 1: Some properties of the surface soil at the start of the experiment

Soil property	Value
Clay (%)	17
Silt (%)	15
Sand (%)	68
Bulk density (Mg m^{-3})	1.35
Organic carbon (%)	0.59
Total N (%)	0.066
pH (H_2O)	4.5
CEC (cmol/kg soil)	5.17
Available P (ppm)	7.4

Effect of spent auto-engine oil contamination on Total Hydrocarbon Content (THC) of soil cultivated to soybean: Increase in the dose of spent engine oil contamination expectedly increased the total hydrocarbon content of the soil (Fig.1).The contamination of the soil with 3 % oil increased total hydrocarbon content from 905 mg kg^{-1} in control soil to 24429 mg kg^{-1} whereas the 1 % contamination increased THC to 7455 mg kg^{-1} in the first 12 months. Samples collected within the first 12 months showed the highest THC which reduced gradually over the next 24 months, reaching a minimum of 20910 mg kg^{-1} and 4615 mg kg^{-1} in 3 and 1 % spent engine oil treated soils respectively. The result generally indicated that THC of treated soils followed a 3 > 2 > 1 > 0 % trend. The reduction of spent engine oil in the contaminated soils with time is thought to be due to biodegradation and down-ward seepage beyond the sampling zone. Avidano *et. al.,* (2005) observed that *Pseudomonas* and *Bacillus* micro-organisms were prevalent in petroleum contaminated sites, whereas dramatic reduction occurred in the total microbial community due to the additions of petroleum waste sludge. Petroleum hydrocarbon utilizers can tolerate oil contaminated environments because they possess the capacity to utilize oil as energy source (Jelena *et. al.,* 1990).On the order hand Katsivela *et. al.,* (2005) reported that petroleum waste sludge adversely affected the microbial population by depleting essential inorganic nutrients and growth factors and lowering the pH immediately around negatively charged soil surfaces.

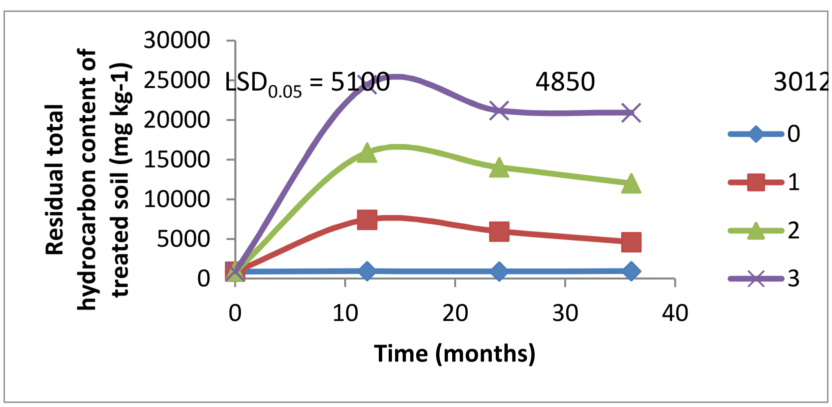

Fig 1: Changes in soil total hydrocarbon content (mean values) following spent engine oil loading

Effect of spent auto-engine oil contamination on infiltration rate of soil cultivated to soybeans: The ease with which water entered the treated soils from the surface is reflected in Fig.2. The result indicated that infiltration rates in plots under 3 % spent engine oil were reduced from 1.40 cm h^{-1} in control plots to the lowest value of 0.07 cm h^{-1} compared to 0.27 cm h^{-1} in 1 % treatment in the first 12 months. The highest infiltration rates of 0.35, 0.37 and 0.41 cm h^{-1} for 3, 2 and 1 % contaminations were observed in the 36th month. Generally the results indicate a gradual increase in infiltration rates from the 12th to the 36^{th} month. This indicated that water could not displace spent oil from the pore spaces but could only succeed the oil following oil loss by the mechanisms of biodegradation and seepage. This could be attributable to the hydrophobicity of oil. Ahamefule *et al*. (2014), Badrul (2015) and Adewole and Moyinoluwa (2012) observed that oil occupied the macrospores and coated macro aggregates, reduced the water film thickness around macro aggregates and as a result retarded the movement of water into soil aggregates.

*Effect of spent engine oil contamination on hydraulic conductivity of soil cultivated to soybean***:** The data presented in Fig.3 reflects the ease with which water redistributed within the treated soils under investigation. It was observed that saturated hydraulic conductivity (K_s) increased with increase in spent engine oil contamination. The K_s values obtained showed lowest decline relative to control in the 3rd month whereas samples taken in the 12^{th} month was found to give the highest post-contamination K_s values. Plots contaminated with 3 % spent engine oil gave relatively the lowest K_s values of 6.29, 7.68 and 9.43 cm h^{-1}while the highest values of 11.68, 13.91 and 16.24 cm h^{-1} were obtained in 1 % treatment in the 12^{th},24^{th} and 36^{th} months respectively. The values showed a change in permeability rating from rapid (K_s > 25 cm h^{-1}) in control soil to moderately rapid (K_s < 15 cm h^{-1}) in 3 % treatment. The K_s values was of the order 0 > 1 > 2 > 3 %.

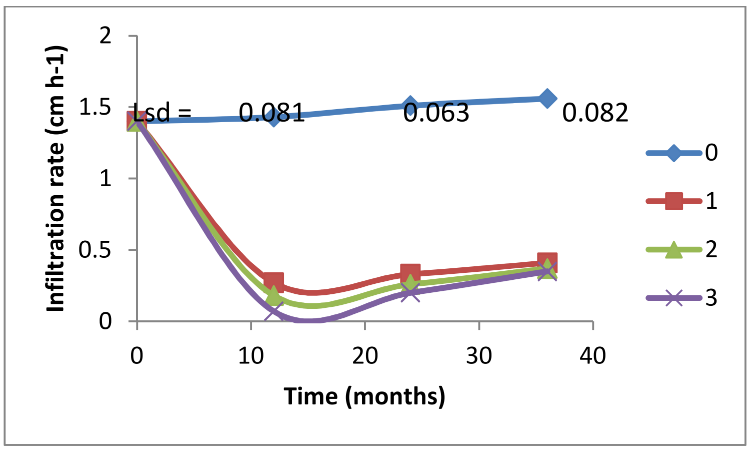

Fig 2: Effect of spent auto engine oil contamination on soil infiltration rate (mean values)

Slight changes in K_s observed in control soils could be attributed to seasonal effects imposed by rainfall and organic matter dynamics while in contaminated plots the effects were in addition due to the hydrophobicity of oil which hampered the movement of water through the soil column.

Effect of spent auto-engine oil on soybean germination, leaf area, dry matter and grain yield: The results indicated that increased oil contamination beyond 1 % had an inhibition effect on the germination of soybean seeds (Table 2). The 2 % and 3 % spent oil contaminations reduced soybean germination from 99 % (control) to 80 and 68 % respectively while soybean germination in plots under 1 % oil treatment did not significantly differ from that in the control (0 %) in 12 months(first cropping season) following oil contamination.

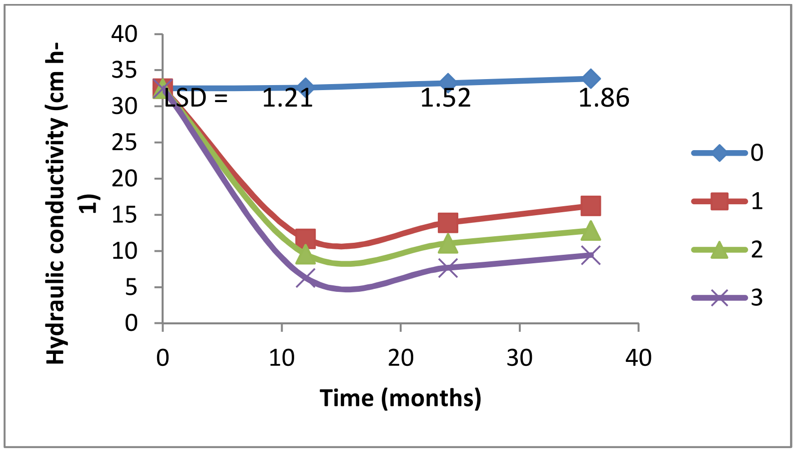

Fig 3: Effect of spent auto engine oil contamination on soil hydraulic conductivity (mean values)

The non-significant difference in germination in the 0 and 1 % spent engine oil contaminated soils indicate that a threshold value of 1 % (10,000 mg kg^{-1} soil) spent engine oil contamination and/or 7500 mg kg^{-1} residual total hydrocarbon content has to be exceeded for a significant decline in soybean germination to occur. Decline in germination began to occur between 7500 – 15902 mg kg^{-1} soil residual total hydrocarbon content. However Vwioko and Fashemi (2005) had reported a positive response of plant seed germination to 1 % spent engine oil. The authors reported stimulation of germination at 1 % w/w spent engine oil in soil for *Ricinus communis* while germination in higher concentrations (2, 3, 4, 5 and 6 % w/w) exhibited depression. In the same vein Anoliefo and Vwioko (2005) and Sharifi *et al.* (2007) separately reported growth enhancement (fertilizer effect) at 1 % spent auto-engine oil contamination when compared to the control, for various plant species. Generally, the behavior of the 1 % spent engine oil may be related to the findings of Odu (1981) who reported that contamination of soil with 1 – 5 % crude oil normally act as a boost to soil organic matter. Differences in crop type, soil heterogeneity and property of oils used in these various experiments may be responsible for the extent of variations in seed germination reported. Above the 1 % spent engine oil contamination used in this work, a range of adverse soil conditions developed. Water infiltration into and distribution within the soil (Fig.2 and 3) which was observed to have been significantly retarded may have starved the germination process of water, much needed for this physiological activity. Included also are the tendency of increased soil temperature (above optimum) due to the imparted dark colour of contaminated soils resulting in increased heat absorption, build-up of toxicity from the spent auto-engine oil and due to anaerobic conditions (Shallu *et al*., 2014). Ekundayo *et. al.,* (2001) working on maize attributed depressed emergence under spent oil contamination to oil coating on seed surfaces which affected physiological functions within the seed. Anoliefo and Vwioko (1995) reported that upon drying, the soils contaminated with spent engine oil became too hard to allow germination.

The 1 % spent oil contamination was observed to have significantly ($P < 0.05$) increased the leaf area of soybean by 4.0 % (54.7 – 52.6 cm^2) while 2 and 3 % led to significant decreases of 6.8 % (52.6 – 49.0 cm^2) and 23.0 % (52.6 – 40.5 cm^2) respectively. The growth enhancement effect of 1 % spent auto-engine oil had earlier been reported by Anoliefo and Vwioko (2005), Vwioko and Fashemi (2005) and Sharifi *et al.* (2007) on maize plant.

Table 2: Effects of spent auto engine oil contamination on germination, leaf area, dry matter and grain yield of soybeans (*Glycine max L.Merril)* in 2007 cropping season.

Spent oil loading (%)	Germination (%)	Leaf area (cm^2)	Dry matter tonnes ha^{-1}	Grain Yield tonnes ha^{-1}
0	99^a	52.6^b	3.02^b	0.71^b
1	99^a	54.7^a	4.21^a	0.97^a
2	80^b	49.0^c	2.51^c	0.67^c
3	68^c	40.5^d	1.80^d	0.11^d

*Figures followed by the same letters within the same column are not significant at $P \leq 0.05$ using Duncan's multiple range test.

Table 3: Effects of spent auto engine oil contamination on germination, leaf area, dry matter and grain yield of soybeans (*Glycine max L.Merril)* in 2008 cropping season.

Spent oil l oading (%)	Germination (%)	Leaf area (cm^2)	Dry matter tonnes ha^{-1}	Grain Yield tonnes ha^{-1}
0	99^a	52.8^b	3.01^b	0.72^b
1	99^a	54.5^a	4.20^a	0.97^a
2	89^b	51.0^c	2.86^c	0.70^b
3	70^c	41.0^d	1.82^d	0.11^c

*Figures followed by the same letters within the same column are not significant at $P \leq 0.05$ using Duncan's multiple range test.

Beyond 1 % spent oil contamination the growth of soybean plant may have been retarded due to the toxic effects of the spent auto-engine oil, nutrient and water deficits as earlier indicated in Fig.2 and 3.

Table 4: Effects of spent auto engine oil contamination on germination, leaf area, dry matter and grain yield of soybeans (*Glycine max L.Merril)* in 2009 cropping season

Spent oil loading (%)	Germination (%)	Leaf area (cm^2)	Dry matter tonnes ha^{-1}	Grain Yield tonnes ha^{-1}
0	100^a	52.7^b	3.01^b	0.72^b
1	99^a	56.0^a	4.17^a	0.91^a
2	98^b	56.0^c	4.16^c	0.88^a
3	74^c	41.8^d	2.00^d	0.13^c

*Figures followed by the same letters within the same column are not significant at $P \leq 0.05$ using Duncan's multiple range test.

Agbogidi (2010) reported similar findings. The effect of spent engine oil on dry matter accumulation and grain yield followed the same trend with that observed for leaf area. The highest dry matter (4.21 t ha^{-1}) and grain (0.97 t ha^{-1}) yield of soybean plants were obtained in plots contaminated with 1 % spent engine oil whereas plots under 3 % contamination gave the lowest dry matter (1.80 t ha^{-1}) and grain (0.11 t ha^{-1}) yield which reflected the sizes and conditions of their leaf surfaces for photosynthesis. It was observed that some of the soybean plants in the 2 % and most in 3 % spent auto-engine oil treatment were chlorotic while some exposed to the higher oil treatment (3 %) failed to yield grains or yielded very low at maturity. Chlorotic leaves will show low photosynthetic efficiency resulting from the absence of chloroplasts and hence may not contribute or contribute little photosynthates in dry matter build-up and grain filling (Ahamefule and Peter, 2014).This invariably resulted in the low dry matter deposition and reduced grain yield observed as spent auto-engine oil contamination increased beyond 1 % especially in the first planting season.

However, in the subsequent planting seasons (2008 and 2009) the results (Table 3 and Table 4) indicated substantial improvements in the plant parameters sampled; particularly in plots under 2 and 3 % spent auto-engine oil contamination. Soybean yield increased from 0.67 t ha^{-1} in 2007 to 0.88 t ha^{-1} in the 2009 cropping season for plants cultivated in soils contaminated with 2 % spent auto-engine oil. For this same period yield in 3 % spent auto-engine oil contaminated plots increased from 0.11 to 0.13 t ha^{-1} whereas there was a drop in yield from 0.97 to 0.91 t ha^{-1} for soybean plants cultivated in soils contaminated with1 % spent auto-engine oil. The result generally indicate that though there was still the presence of spent auto-engine oil in all the contaminated plots at the 36th month of sampling, it was only detrimental to soybean growth and yield at the 3 % level.

*Conclusions***:** This study has shown that spent auto-engine oil above 1 % v/w soil contamination significantly deteriorated water movement into and within the experimental soil and consequently the growth and yield of soybean was adversely affected; however the effect naturally weaned beyond a year depending on the quantity spilled.

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