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Effect of different levels of spent engine oil on soil porperties, grain yield of maize and its heavy metal uptake in Abakaliki, Southeastern Nigeria

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This research was carried out at the Plant and Screen house to study effect of different levels of spent engine oil application on soil properties, grain yield of maize and heavy metals uptake. Completely randomized design was used with nine treatment levels of spent engine oil at 0.0, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8 and 1.0 L were applied to 20 kg of soil. Maize was used as a test crop. Data collected from the study were subjected to Statistical Analysis System for Agricultural Research. Spent engine oil at 1.0 l/poly bag significantly (P<0.05) increased bulk density by 24% and reduced gravimetric moisture content, total porosity and hydraulic conductivity by 125, 43 and 186% respectively when compared with the control. Similarly, organic carbon and nitrogen were significantly (P<0.05) higher by 152 and 87% when spent engine oil was applied at 1.0 l/poly bag relative to control. Furthermore, available P, exchangeable K, Mg, Na and Ca were 143, 123, 67, 34 and 48% significantly (P<0.05) lower at 1.0 l/poly bag of spent engine oil treatment compared with the control. Spent engine oil applied at 1.0 l/poly bag severely affected physicochemical properties of soil more than other levels except for OC and N. Maize seed germination was lower and delayed for minimum of 7 days at 1.0 l/poly bag of spent engine oil application. Grain yield of maize was significantly (P<0.05) lower with spent engine oil application than control. There were 197 and 83% reductions in grain yield of maize and seed germination relative to control. Significantly (P<0.05) higher lead and cadmium uptake by maize seeds was obtained in plots receiving spend engine oil. Contamination of soil with spent engine oil should be avoided in order to ensure sustainable soil productivity and risk of heavy metals toxicity of human beings.

Key words: Effect, grain yield, levels, heavy metal uptake, soil properties.

INTRODUCTION

In urban areas, various types of activities like agriculture, industry and transportation produce large amount of wastes which are classified as either agricultural, industrial, municipal or nuclear wastes (Onwuka et al.,

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2012). These wastes from various sources are deposited on the soil surfaces either deliberately applied as fertilizer, sprays or pesticides (Lauhanen et al., 2004) or inadvertently through small or large leaks (Adesodun, 2014) as solids, plastics, crude oil or spent engine oil. Some of these wastes can be recycled into some important products that can be used to meet with the challenges arising from increasing population of Nigeria. They can be recycled into manures and fertilizers for production of crops and animals among others (Onwuka et al., 2012). There are others that cannot be converted into any beneficial secondary use and therefore pose a serious threat to the environment and one of such is spent engine oil (Onwuka et al., 2012).

Spent oil sometimes referred to as waste engine oil is produced from automobile mechanic shops and mechanical or electrical engine repairers' shops (Anoliefo and Vwioko, 2001) after servicing the vehicles engines, generating set and other types of engines. It has dark brown to black colour and it is harmful to the soil environment (Adedokun and Ataga, 2007). This is because it contains a mixture of different chemicals including low to high molecular weight (C_{15}-C_{21}) compounds, lubricants, additives and decomposition products and heavy metals which have been found to be harmful to the soil and human health (Duffus, 2002).

According to Ekundayo et al. (1989), marked change in properties occurs in the physical, chemical and microbiological properties of soils contaminated with lubricant oil. Oil displaces air and water leading to anaerobic condition (Atlas, 1977). The presence of spent lubricant oil in soil increases bulk density, decreases water holding capacity and aeration propensity (Kayode et al., 2009). The authors also noted reduced nitrogen, phosphorus, potassium, magnesium, calcium, sodium and increased levels of heavy metals in soils contaminated with spent oil. In contrast, Vwioko et al. (2006) noted build up of essential elements such as organic carbon and organic matter and their eventual translocation to plant tissues.

These conditions generally cause unsatisfactory seed germination, growth and yield in soil contaminated with spent engine oil. For instance, Odjegba and Sadiq (2002) reported low yield and decreased growth of plant grown in spent lubricant oil contaminated soil. In most cities and towns in Nigeria, some farmers or residents grow vegetables, maize and other crops around the mechanic villages or sink borehole without considering the health risks involved. Researchers such as Wang et al. (2000), Odjegba and Sadiq (2002), Agbogidi and Nweke (2006) and Okonokhua et al. (2007) had worked on effect of spent lubricant oil contamination on soil properties and crop yield but not much work has been carried out on heavy metals uptake by crops in Abakaliki areas. Therefore, the objectives of this study were to study effect of different levels of spent engine oil on soil properties, grain yield of maize and its heavy metals uptake.

MATERIALS AND METHODS

Study site

The research was carried out at the Plant and Screen house of the Faculty of Agriculture and Natural Resources Management, Ebonyi State University, Abakaliki. The area is located by latitude 06°4/N and longitude 08°65/E in the derived Savanna of the southeast agro ecological zone. Bimodal pattern of rainfall which is spread from April- July and September – November is a common experience within the area and there is break in August usually referred to as "August break" the minimum and maximum rainfall ranges from 1700 to 2000 mm with mean annual rainfall of 1800 mm. The temperatures are 27 and 31°C for minimum and maximum and is also even through out the year. The relative humidity is 60% during dry season but increases to 80% in rainy season. The soil of the area is derived from marine deposits. Abakaliki are lies within "Asu River group and consists of Olive brown sandy shales, fine grained sands stones and mudstones. The soils are shallow with unconsolidated parent material (Shale residuum) within 1 m of the soil surface. The soil belongs to the order ultisol and is classified as Typic Haplustult (FDALR, 1985).

Experimental design/layout and treatment application

The experiment was laid out using Completely Randomized Design (CRD) in a Plant and Screen house of the Faculty of Agriculture and Natural Resources Management, Ebonyi State University, Abakaliki. Perforated poly bags were filled with 20 kg of soil and arranged at 0.5 m space between poly bags and 1 m between replications. The soil was collected and bulked, dried and passed through 2 mm sieve before weighing into the poly bags. There were a total of nine treatments namely 0, 0.3, 0.4, 0.5, 0.6, 0.7. 0.8, 0.9 and 1.0 L/poly bag of 20 kg soil. These treatments were replicated three times to give twenty-seven experimental units. The spent engine oil was collected from mechanic workshop at Abakaliki, Ebonyi State. The treatments were thoroughly mixed with each 20 kg soil before filling it in the poly bags and allowed for two weeks before planting the maize seeds. Maize variety (Oba supper II) hybrid sourced from Ebonyi State Agricultural Development Programme, Onu Ebonyi Izzi, Abakaliki was used as a test crop. The maize seeds were planted at 2 per hole in each poly bag at a planting distance of 10 x 10 cm. Two weeks after germination (WAG), thinning was done to allow a plant per hole. Germination count was carried out subsequently. Fertilizer, NPK 15:15:15 at 400 kg ha^{-1} equivalent to 7.8 g/poly bag was applied at two weeks after planting on all the poly bags. Weeding was done by hand picking at regular intervals and carried out till harvest.

Soil sampling

Auger and core soil samplers were used to collect soil samples from each poly bag and also from site where soil used for filling the poly bags was collected for pre-planting and post harvest soil analysis. Core soil samples were used to determine soil physical properties. Auger soil samples were sieved with 2 mm sieve and used for soil chemical properties determination.

Agronomic data

Germination count was taken at 1 week after planting and calculated as:

Table 1. Properties of soil before contamination and heavy metals concentration of spent engine oil.

Soil properties	Values
Sand (gkg^{-1})	690
Silt (gkg^{-1})	110
Clay (gkg^{-1})	200
Textural class	Sandy loam
pH	5.0
Organic Carbon (%)	0.46
Nitrogen (%)	0.04
Phosphorus ($mgkg^{-1}$)	58.20
Calcium ($cmolkg^{-1}$)	5.60
Magnesium ($cmolkg^{-1}$)	4.00
Potassium ($cmolkg^{-1}$)	0.16
Sodium ($cmolkg^{-1}$)	0.16
Spent engine oil	
Zinc ($mgkg^{-1}$)	19.30
Lead ($mgkg^{-1}$)	39.75
Copper ($mgkg^{-1}$)	16.85
Cadmium ($mgkg^{-1}$)	10.56
Organic carbon (%)	17.3
Nitrogen (%)	6.8
Available phosphorus ($mgkg^{-1}$)	0.02

$$\text{Germination count \%} = \frac{\text{Number of germinated seeds}}{\text{Number of seeds planted per poly bag}} \times \frac{100}{1}$$

Maize grain yield was determined from four tagged plants from each poly bag. The cobs were harvested when the husks were dried, dehusked, shelled and grain yield adjusted to 14% moisture content.

Laboratory methods

Particle size distribution (PSD) was determined by hydrometer method as described by Sheldrick and Wang (1993). Bulk density determination was carried out using the method of Black and Hartge (1986). Total porosity was calculated using Obi (2000) method. Hydraulic conductivity was determined using Klute and Dirksen (1986) technique. Gravimetric moisture content was calculated using Obi (2000) method. Soil pH in water was determined in soil/water ratio of 1:2.5. The values were read off using glass electrode pH meter (Tel and Hagarty, 1984). Organic carbon determination was by Walkley and Black method as outlined in Page et al. (1982). Total nitrogen was determined using microkjelhdal procedure (Bremner and Mulvancy, 1982). Available phosphorus was measured using Bray -2 method (Page et al., 1982). Exchangeable cations of calcium (Ca) and magnesium (Mg) were determined using titration method (Mba, 2004) while sodium (Na) and potassium (K) determination was done using flame photometry method (Ohiri and Ano, 1985). Determination of crop uptake of cadmium (Cd) and lead (Pb) was done using atomic spectrophotometer (AAS) according to Dewis and Freitas (1976).

Data analysis

The soil and maize data were subjected to analysis of variance (ANOVA) according to SAS (1985). Means were separated using Fisher's Least Significant Difference (FLSD). Significance was reported at 5% probability level.

RESULTS AND DISCUSSION

Initial properties of soil and spent engine oil

The properties of soil before contamination and concentration of nutrients in spent engine oil are presented in Table 1. The textural class was sandy loam. The pH value was 5.0 and this was rated as strongly acidic (USDA SCS, 1974). Organic carbon (OC) and total nitrogen (N) recorded low values according to Landon (1991) rating. Available phosphorus was high (Enwezor et al., 1982). Exchangeable calcium (Ca) and magnesium (Mg) dominated the exchange complex of soil. Heavy metals concentration in spent engine oil (Table 1) indicated that the values of Zn, Pb, Cu and Cd were within normal safe range in soils (Alloway, 1990). The percentage organic carbon and nitrogen were respectively high (Enwezor et al., 1989). Available phosphorus was very low (Landon, 1991).

Soil physical properties

Table 2 shows effect of spent engine oil on soil physical properties. Bulk density of spent engine oil treated soil

Table 2. Effect of spent engine oil on soil physical properties.

Treatment	BD(gcm^{-3})	GMC (%)	TP (%)	HC($Cmhr^{-1}$)
0.0	1.50	47.98	43.67	3.99
0.3	1.65	14.47	37.67	2.90
0.4	1.71	13.52	35.00	2.68
0.5	1.74	13.45	34.00	2.55
0.6	1.78	13.14	32.67	1.49
0.7	1.80	12.55	32.33	1.24
0.8	1.85	12.24	30.33	1.11
0.9	1.88	12.16	29.00	0.83
1.0	1.90	11.07	28.33	0.14
FLSD (0.05)	0.06	4.39	2.42	1.05

BD – Bulk density, GMC –Gravimetric moisture content, TP-Total Porosity, HC - Hydraulic conductivity

was significantly ($P<0.05$) higher than the control. The bulk density of spent engine oil treated soil generally increased with increase in levels of spent engine application with the one receiving 1.0 l/poly bag recording a correspondingly highest value. The bulk density of soil treated with 1.0 l/poly bag of spent engine oil was significantly ($P<0.05$) higher than those treated with 0.3 to 0.7 l/poly bag of soil, respectively). These were 13, 10, 8 and 6% higher when compared with 0.3, 0.4, 0.5 and 0.6 l/poly bag of spent engine oil application. The result further showed that gravimetric moisture content (GMC), total porosity and hydraulic conductivity of control were significantly ($P<0.05$) higher compared to the ones receiving spent engine oil treatment. Gravimetric moisture content generally decreased across the treatments with 1.0 l/poly bag application of spent engine oil having least GMC. However, there was no significant difference in GMC among the engine oil treatments. There was inverse relationship between bulk density and total porosity as affected by spent engine oil application. Furthermore, total porosity decreased with increase in spent engine oil application. The poly bag receiving 0.3 L of spent engine oil had significantly ($P<0.05$) higher total porosity relative to those treated with higher levels of spent engine oil, respectively. Similarly, total porosity of soil treated with 0.4 L of spent engine oil was significantly ($P<0.05$ higher than those receiving higher spent engine oil expect for 0.5 L application of spent engine oil. Significantly ($P<0.05$) higher hydraulic conductivity was obtained in soils treated with 0.3, 0.4 and 0.5 L of spent engine oil when compared to those of higher oil treatment.

The significant increase in bulk density of spent engine oil treated soil could be attributed to compaction resulting from oil contamination as well as reduced porosity. Kayode et al. (2009) reported increased bulk density in soil contaminated with spent lubricant oil. The bulk density values were above critical limits for soil productivity (Grossman and Berdanier, 1982). Compaction of soil also caused reduction in total porosity as the pore spaces could have been clogged by dispersed soil particles. Nwite (2013) reported a similar soil condition in his study of soil contaminated with spent lubricant oil. Water is stored in pore spaces free of air and other blockages, consequently low gravimetric moisture content was expected in soils treated with spent engine oil since there was high bulk density and reduced total porosity. Rasaiah et al. (1990) observed decreased soil water retention capacity in soils contaminated with spent hydrocarbon oil. Low hydraulic conductivity in soils contaminated with spent engine oil could be as a result of distortion, blockage or displacement of water by air in pore spaces. Agbogidi and Enujeke (2012) noted that plots which received spent oil treatment had reduced water infiltration and percolation. Reduced hydraulic conductivity implies low “soil water transmission” and less water would be available for plant roots to access for photosynthetic processes.

Effect of spent engine oil on soil chemical properties

Although, pH was generally higher and increased with increase in spent engine oil application across treatments, there was no significant ($P<0.05$) difference among the plots receiving different levels of spent engine oil and the control. The percent organic carbon (%OC) across the treatments of spent engine oil was significantly ($P<0.05$) higher than control. The organic carbon of spent engine oil applied at 1.0 l/poly bag significantly ($P<0.05$) increased relative to other levels of spent engine oil treatments. Organic carbon of spent engine oil applied at 1.0 l/poly bag was higher by 86% when compared with the control. Similarly, percent (%N) of spent engine oil contamination across the treatments was significantly ($P<0.05$) higher than that of the control except the ones applied at 0.3 and 0.7 l l/poly bag. Nitrogen content of soil increased with increase of oil application except for 0.7 l/ploy bag. Percent nitrogen content of spent engine oil applied at 1.0 l/poly bag was 61% higher than control.

Table 3. Effect of spent engine oil on soil chemical properties.

Treatment	pH (H_2o)	(%) OC	N (%)	P ($mgkg^{-1}$)	K	$Cmolkg_{-1}$ Mg	Na	Ca
0.0	5.20	0.44	0.11	61.30	0.21	4.00	0.17	5.20
0.3	5.51	2.50	0.14	46.50	0.14	3.60	0.16	4.80
0.4	5.34	2.63	0.18	40.40	0.14	3.20	0.15	4.80
0.5	5.51	2.55	0.18	40.20	0.12	2.80	0.15	4.80
0.6	5.35	2.63	0.14	39.70	0.12	2.80	0.14	4.00
0.7	5.27	2.83	0.10	27.50	0.07	2.40	0.14	4.00
0.8	5.52	2.38	0.17	27.50	0.06	2.40	0.14	4.00
0.9	5.50	3.03	O.25	20.50	0.06	2.00	0.13	3.60
1.0	5.73	3.19	0.28	10.20	0.05	2.00	0.12	3.20
FSLD (0.05)	NS	0.21	0.04	1.58	0.02	0.42	0.02	0.46

However, available phosphorus of control was significantly ($P<0.05$) higher than those of spent engine oil application across the treatments. Available phosphorus also decreased with increase in spent engine oil application with the one applied at 1.0 l/poly bag giving the least value of 10.20 mg kg^{-1}. The available phosphorus of control was 83% higher than the one applied at 1.0 l/poly bag. Exchangeable cations of K, Mg, Na and Ca were generally higher in control than in different levels of spent engine oil application. Except for spent engine oil applied at 0.3 l/poly bag for Mg, exchangeable K and Mg of control were significantly ($P<0.05$) higher compared to those of spent engine oil contamination at other levels of treatments. The exchangeable K and Mg also decreased with increase in spent engine oil treatment. Exchangeable K was lowest at 1.0 l/poly bag of spent engine oil application and this accounted for 76% decrease when compared with the control. Exchangeable Na was significantly ($P<0.05$) higher than those of plots treated with of spent engine oil except for the one applied at 0.3 l/poly bag. Furthermore, exchangeable Ca of control was significantly ($P<0.05$) higher than those of 0.6 l/poly bag and 1.0 l/poly bag application, respectively, Exchangeable Ca and Mg were predominantly higher in the exchange complex of soil.

The no significant difference between different levels of spent engine oil application and control in pH suggests that spent engine oil has no serious negative impact on soil pH. This observation was corroborated by Okonokhua et al. (2009) in their study that there was no significant difference between control and spent oil treated soil. The pH values of the treatments according to Landon (1991) were slightly acidic. The significant increase in percent organic carbon and Nitrogen of spent engine oil treated soil relative to control could be attributed to effect of spent engine oil contamination of soil. Spent engine oil application could increase levels of organic carbon and Nitrogen of soil. This could be due to input arising from the content of mineral elements in the oil. Okonokhua et al. (2007) reported increase in carbon and nitrogen of spent lubricant oil treated soil relative to control. In contrast, Kayode et al. (2009) observed that there was reduced nitrogen in soil treated with spent lubricant oil. Spent engine oil applied on soil has beneficial effect since it can increase organic carbon and nitrogen content in soil. The significant decrease of available phosphorus could be attributed to deleterious effect of spent engine oil application on soil. Spent engine oil in soil could inhibit microbial transformation of organic matter thus, leading to low mineralization of phosphorus. Furthermore, acidic nature of the soil could have affected phosphorus availability in the soil since it can be fixed by aluminum at low pH. Ogboghodo et al. (2004) noted that available P was low in soil treated with spent lubricant oil.

The application of spent engine oil depressed availability of exchangeable cations. This could be due to low pH of the soil as well as other enhancing nutrients such as available P. Several researchers (Kayode et al., 2009; Uhegbu et al., 2012) have respectively reported reductions of exchangeable cations in soils treated with spent lubricant oil. All the chemical properties of soil studied indicated severity as the levels of spent engine oil application increased indicating that high disposal of hydrocarbon oil into the soil poses a great danger of soil degradation and low productivity.

Effect of spent engine oil on maize germination and grain yield

Table 4 shows effect of different levels of spent engine oil application on germination of maize and grain yield. Germination of maize seed one week after planting (WAP) was generally high in all treatments. However, germination declined to 92% each in spent engine oil treated soil at 0.8 and 9.0 l/poly bag, respectively. The soil receiving 1.0 l/poly bag of spent engine oil had 83% germination after one week.

Maize grain yield was significantly ($P<0.05$) higher in control compared to those receiving spent engine oil

Table 4. Effect of spent Engine oil on seed germination and maize grain yield.

Treatment	Germination (%)	Grain yield of maize (g/plo bag)
0.0	100	23.47
0.3	100	11.75
0.4	100	4.87
0.5	100	2.07
0.6	100	0.84
0.7	100	0.66
0.8	92	0.30
0.9	92	0.27
1.0	83	0.20
FLSD 0.05	-	5.09

Table 5. Heavy metals of lead and cadmium uptake by maize grains.

Treatment	mgkg^{-1}	
	Pb	Cd
0.0	0.03	0.03
0.3	0.06	0.04
0.4--	0.06	Trace
0.5	0.07	0.07
0.6	0.08	0.06
0.7	0.05	0.06
0.8	0.05	0.06
0.9	0.08	0.06
1.0	0.11	0.7
FLSD (0.05)	0.02	0.02

treatments across all the levels. Similarly, soil treated with 0.3 l/poly bag of spent engine oil had significantly (P<0.05) higher grain yield of maize when compared to those receiving higher oil treatments. Essentially, grain yield of maize decreased with increase in spent engine oil application.

Low and delayed germination of maize seeds in soil receiving higher spent engine soil treatment indicate degree of soil degradation. Ekundayo et al. (2001) noted that germination of seeds was delayed in oil polluted soil. The maize seeds in control germinated within five days of planting. Those planted in poly bags receiving higher spent engine oil germinated between seven to ten days. This finding was reported by Onwuka et al. (2012) in their study of effect of spent engine oil on seed germination. The significant low maize grain yield in soil receiving spent engine oil treatment showed negative effect of the oil on crop yield. Low nutrients (Table 3) could have contributed to decreased yield of maize. Since oil contamination of soil could cause soil degradation, low maize yield is anticipated. This is in line with the findings of Adeoye et al. (2005) that hydrocarbon oil reduced soil quality and crop yield. This was also corroborated by Rainbow (2007) that spent lubricant oil caused soil degradation and low crop yield. Several other researchers (Odjegba and Sadiq, 2002; Wang et al., 2002) corroborated the earlier report on low yield of crops on spent lubricant oil contaminated soil.

Heavy metals uptake by maize grains

Table 5 shows heavy metals uptake by maize grains. The uptake of lead by maize grains was significantly (P<0.05) higher in the poly bags treated with spent engine oil when compared with the control. The poly bags receiving 1.0 l/poly bag of engine oil had significantly (P<0.05) higher lead content in maize grains relative to other maize grains planted in poly bags treated with lower levels of engine oil, respectively. Lead uptake in maize grains generally increased with increase in spent engine oil application, although there was decline in poly bags receiving 0.7 and 0.8 L of oil treatment. Similarly, cadmium uptake in maize grains was significantly (P<0.05) higher in poly bags receiving spent engine oil treatment compared with control except in 0.3 and 0.4 l/ploy bags of spent engine oil contamination. Even though, cadmium uptake by maize grain generally increased with spent engine oil application, there was no significant (P<0.05) difference among the treatments.

The significantly higher uptake of lead (Pb) and cadmium (Cd) by maize grains in poly bags treated with spent engine oil could be attributed to release of those heavy metals into soil due to application of spent engine oil. Adweole et al. (2008) reported heavy metals uptake by crops in their work and noted that these heavy metals were stored in crop parts. The implication is that human beings are at risk of heavy metals toxicity. Anikwe and Nwobodo (2002) and Asadu et al. (2008), in their findings observed that human beings were at risk of heavy metals toxicity if they would utilize crops grown around areas polluted with heavy metals due to heavy metals eco-toxicity. This could be possible through recycling of heavy metals through food chain. Heavy metals of lead and cadmium have the capacity to cause brain, renal or reproductive disorders in human beings. Lead uptake by maize grains was generally higher than cadmium. This suggests that man is at higher risk of lead toxicity when he takes crops grown in spent engine oil treated soils.

Conclusion

The results of this study have shown that application of spent engine oil has deleterious effect on physico-chemical properties of soil and grain yield of maize as well as its heavy metals uptake. The application of spent engine oil increased bulk density, reduced total porosity, moisture retention capacity of soil and water transmission. Similarly, available phosphorus as well as exchangeable cations were generally depressed due to spent engine oil application. Maize seed germination was delayed and equally inhibited because of spent engine oil treatment. Heavy metals of lead and cadmium uptake by maize grain although not at critical levels, pose danger to human health since human beings depend on crops for their nutrition.

Conflict of Interest

The authors have not declared any conflict of interest.

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