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Contamination level of spent engine oil in the rhizosphere of *Arachis Hypogea* L.

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One of the prevalent soil contaminants in Nigeria is spent engine oil (SEO). This experiment aimed to evaluate how spent engine oil affected various heavy metals and mineral composition in the rhizosphere of *Arachis hypogaea* L. Concentrations of 0 (control), 100, 200 and 300 ml of SEO were used to pollute soil bags containing *A. hypogaea* plants, respectively. In the Botanic Garden of the University of Nigeria, Nsukka, they were put up in 9 repetitions in a completely randomized manner. The soil was tested for heavy metals and mineral components after three months of contamination. In a dose-dependent manner, the data revealed a significant (P 0.05) rise in pH, organic matter, and carbon. The concentrations of lead, zinc and iron increased drastically as the concentration of SEO increased, from 0.57 in the control to 1.89 with 300 ml effluent for lead, 1.66 to 1.73 (iron) and 0.95 to 1.48 mg/kg (zinc) according to heavy metal analyses. SEO application did not negatively alter soil texture, but it did greatly improve soil cation exchange capacity, nitrogen, accessible phosphorus, and other mineral nutrients, according to the study. In conclusion, despite heavy metal deposition, the groundnut plant's rhizosphere action may have improved the mineral contents of the soil. However, more research is needed to determine the metal uptake by the plant and its potential use in phytoremediation.

Key words: *Arachis hypogaea,* environmental pollution; heavy metals; phytoremediation; spent engine oil.

INTRODUCTION

With an ever-increasing human population comes a rise in the demand for energy for transportation, residential, and industrial purposes. Since the 1950s, petroleum-based (fossil) fuels have been the primary source of energy (Ismail et al., 2014). Increased usage of petroleum and its derivatives, such as gasoline, diesel, and motor lubricants, has resulted in significant soil degradation around the world, as well as greenhouse gas emissions that contribute to climate change (Nowak et al., 2019). In both industrialized and developing countries, the environmental impact of petroleum exploration, production, refining, and transportation are a serious problem (Okieimen and Okieimen, 2005). Spent engine oil (SEO) is a petrochemical that has been identified as large and widespread soil contamination in Nigeria (Sharifi et al., 2007).

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After servicing and draining used oil from vehicles and generator engines, SEO is obtained. It includes heavy metals and potentially hazardous polycyclic aromatic hydrocarbons (Sharifi et al., 2007). However, the amount and type of heavy metals present in the waste are determined by the manufacturing process (Fowzia and Fakhruddin, 2018). It is thrown into gutters, water drains, open unoccupied plots, and farms indiscriminately by auto technicians and affiliated artisans with workshops on roadsides and open spaces (Anoliefo and Vwioko, 2001). Pollution of water bodies, poisoning of groundwater, and toxicity in animals and plants are all effects. Engine oil is made up of a complicated mixture of hydrocarbons that make up 80 to 90% of its volume and performance-enhancing additives that makeup 10 to 20% of its volume before it is used (Chris, 2007; Mandri and Lin, 2007). Engine oil undergoes a transformation throughout usage due to the breakdown of additives, contamination with combustion products, and the accumulation of metals such as Magnesium, Copper, Zinc, Lead, Cadmium, and others from the engine's wear and tear (Moneke and Nwangwu, 2011; Odukoya et al., 2019). Aliphatic and aromatic hydrocarbons such as phenol, naphthalene, benzo (a) anthracene, benzo (a) pyrene, and fluoranthene are important components of ordinarily used motor oil (Shukry et al., 2013). The illicit dumping of SEO is a worldwide environmental issue with global consequences (Blodgett, 2001). In Buea, Cameroon, Akoachere et al. (2008) identified the discharge of spent crankcase oil from vehicles as a major source of oil pollution. Thenmozhi et al. (2011) and Ugoh and Moneke (2011) both reported soil pollution in the Pudukkottai district of India and the Gwagwalada area of Nigeria, respectively, due to the discharge of old engine oil.

Various pollutants, such as used engine oil and heavy metals, have been discovered to impact soil biochemistry, including microbial characteristics, pH, oxygen availability, and nutrient availability (Ismail et al., 2014). According to recent research, plant roots provide a beneficial environment for bacteria that degrade hydrocarbons (Ismail et al., 2014). Plant age, soil conditions, the genotype of the microorganisms and plants involved, as well as ambient circumstances, all influence the diversity and organization of bacterial communities (Ismail et al., 2014).

Plants are used in phytoremediation to eliminate pollutants from the environment or render them harmless (Ajuziogu et al., 2019). Several plant species have been proven to be capable of growing in polluted soils and extracting pollutants from the growth media. These plants have a variety of functions (Malairajan et al., 2015). Toxic heavy metals can build up in the tissues of some plants (Ndimele et al., 2010). The rhizosphere, or the area around plant roots, has higher populations, diversities, and activity of microorganisms than soil without plants (Ukaegbu-Obi and Omeh, 2014).

Rhizosphere microorganisms are particularly important for plant colonization of unfavorable soils because they can help plants cope with biotic and abiotic stress. As a result, green technology has emerged that uses the symbiotic interaction between plants and their rhizo-microorganisms to break down toxins and clean up the environment. Rhizoremediation is the name for this Microbes in the rhizosphere are sometimes the primary contributors to the degrading process. Exudates from plants are released into the soil ecosystem, increasing microbial activity and assisting in the breakdown of xenobiotics. Enzymes, amino acids, sugars, and low molecular weight carbohydrates are all found in the soluble root exudates (Ukaegbu-Obi and Omeh, 2014). Rhizospheres are also physically stable, eliminating the potentially negative impacts of naturally occurring perturbations on the composition or activity of microbial communities (Ukaegbu-Obi and Omeh, 2014). This stimulating rhizosphere impact has been known for a long time and was initially described by Hiltner in 1904 (Kuiper et al., 2004).

Plant roots provide nutrients other than pollutants to degrading microflora in rhizoremediation, and they also aid in spreading degrading microbes to new areas in the soil (Dunfield and Germida, 2001). Because of their ability to fix nitrogen, legumes have an advantage over other plants in phytoremediation. In oil-contaminated areas, they don't have to fight with microbes and other plants for limited supplies of accessible soil nitrogen. Groundnut (*Arachis hypogea* L.) is a major legume crop that provides an inexpensive source of food for the typical Nigerian. It is a legume that is native to South America, Mexico, and Central America and belongs to the Fabaceae family. It is one of the most important oilseed crops on the planet (Iwo and Obok, 2008; Osuagwu et al., 2017). This study aimed to assess the effect of spent engine oil on some heavy metals and mineral constituents of the rhizosphere of *Arachis hypogaea* L. (Fabaceae).

MATERIALS AND METHODS

The experiment was conducted in the Botanic Garden of the University of Nigeria, Nsukka's Department of Plant Science and Biotechnology, while soil analyses were conducted in the same institution's Department of Soil Science. In a 1:5 ratio, topsoil was mixed with poultry manure (that is 1 kg of poultry manure and 5 kg of topsoil). Before they were employed in the experiment, the mixture was allowed to cool for two weeks. For the planting, ten kilograms of the mixture were placed into several cellophane bags. *A. hypogaea* seeds (3 seeds) were planted at a depth of 5 cm and left to sprout and later trimmed to one plant per bag. The study used a Completely Randomized Design (CRD). This included four (4) treatments (0 - control, 100, 200 and 300 ml of SEO) with nine (9) replicates of each.

After one month of planting, the set-up was polluted with used SEO in different proportions. SEO was employed at concentrations of 0 ml (control), 100 ml, 200 ml, and 300 ml. Soil samples from each treatment were collected two months later and sent to the University of Nigeria, Nsukka's Department of Soil Science for study.

Mineral constituent analyses were performed on soil samples before and after pollution with various quantities of used SEO, using Okonokhua et al. (2007) and Nwite and Alu (2015) techniques.

Table 1. Effect of SEO on the carbon, organic matter and pH of *A. hypogaea* rhizosphere.

Soil treatment	C (%)	OM (%)	pH (H_2O)	pH (KCl)
Control (0 ml)	1.09 ± 0.00^{d}	2.01 ± 0.00^{c}	6.90 ± 0.10^{b}	6.25 ± 0.05^{d}
100 ml	1.17 ± 0.00^{c}	2.01 ± 0.00^{c}	7.60 ± 0.00^{a}	6.79 ± 0.01^{b}
200 ml	1.19 ± 0.00^{b}	2.12 ± 0.00^{b}	7.75 ± 0.05^{a}	6.98 ± 0.03^{a}
300 ml	1.23 ± 0.00^{a}	2.35 ± 0.00^{a}	7.60 ± 0.00^{a}	6.45 ± 0.05^{c}

Means with different letters as superscripts along a column are significantly different at $p \leq 0.05$.
Source: Authors

pH (H20 and KCl), sodium, potassium, magnesium, calcium, nitrogen, exchangeable acidity, aluminium, and hydrogen were among the minerals tested. The heavy metal content of soil samples was determined using AOAC techniques (2003). In a Kheldjal digestion chamber, a known quantity (10 g) of each of the soil samples was digested with 25 ml conc. H2SO4 and catalyst mixtures until they produced clear liquids. The solution was cooled and diluted with distilled water to a volume of 250 mL before being stored. Chromium, lead, cadmium, iron, and zinc were among the heavy metals examined.

Data analysis

With the help of IBM Statistical Product and Service Solution (SPSS) version 20, the data were subjected to analysis of variance (ANOVA), and significant means were separated using Duncan's New Multiple Range Test (DNMRT).

RESULTS

The percentage carbon concentration significantly ($p < 0.05$) increased with an increase in the concentration of SEO contamination. Soil treated with 300 ml SEO recorded significantly ($p < 0.05$) the highest C. The result also showed a significant increase in organic matter with an increase in SEO concentration. However, 100ml SEO had no significant effect on the organic matter as a control sample and 100 ml SEO recorded similar values (Table 1). There was a significant ($p < 0.05$) increase in the pH of the treated soil compared with that of the control. The pH across the soil treated with different concentrations of SEO did not vary significantly ($p < 0.05$), but were all significantly higher than the pH of the control soil. On the other hand, the result of pH dissolved with KCl varied significantly ($p < 0.05$) within the soil treated with different concentrations of SEO, with soil treated with 200 ml of SEO recording significantly the highest pH value (Table 1).

The effect of SEO on soil exchangeable cations was also evaluated and presented in Table 2. Percentage nitrogen significantly ($p < 0.05$) increased in 200- and 300- ml SEO treated soil samples as compared to the control, while soil treated with 100ml concentration did not differ from the control. The percentage base salt showed a significant ($p < 0.05$) dose-dependent decrease across the treated soil. Na^{+} was also observed to increase with pollution, with soil treated with 300 ml SEO having significantly the highest concentration while the control soil had the lowest. The control soil had the lowest Ca^{2+} when compared with the treated soils and there was a significant increase in the Ca^{2+} with an increased concentration of SEO treated samples. There were no significant differences for K^{+} and Mg^{2+} across the control and treatment groups. The H^{+} increased during the experiment from 1.27 ± 0.01 me/100 g in the control soil to 1.67 ± 0.00 me/100 g in the 300 ml SEO treated soil. Available phosphorus was similarly found to increase significantly ($p < 0.05$) with the application of SEO in a dose-dependent manner (Table 2).

The result as presented in Figure 1 shows the particles size parameters of the soil rhizosphere of *A. hypogaea.* The percentage of clay and fine sand in the soil samples polluted with 100 and 200ml SEO decreased significantly ($p < 0.05$) when compared with the control. The concentration of silt was higher in treated soils compared with the control. However, the increase in the silt content was not significant except between the control and 100 ml treatment (Figure 1).

The result presented in Table 3 shows the heavy metal concentration of *A. hypogaea* rhizosphere treated with different concentrations of SEO compared with the control soil. The lead concentration ranged from 0.59 to 1.92 mg/kg across the treatments. There was a dose-dependent increase in lead concentration with the control soil recording significantly the lowest (0.57 ± 0.00 mg/kg) compared with the samples treated with SEO. Chromium and Cadmium all had a concentration below 0.001 mg/kg across the different treatments during the experiment. Similarly, there was an improvement in the iron and zinc concentration with increased concentration of SEO treatment. The iron concentration ranged from 1.65 to 1.73 mg/kg with soil treated with 300 ml SEO recording significantly ($p < 0.05$) with the highest concentration and the control soil with the least value. The zinc concentration was increased significantly ($p < 0.05$) with the application of SEO in a dose-dependent manner.

DISCUSSION

The goal of this study was to see how discarded engine

Table 2. Effect of SEO on %N, available P and exchangeable cations of *A. hypogaea* rhizosphere.

	%		(me/100 g)							
Soil treatment	**N**	**Base salt**	**Na^+**	**K^+**	**Ca^{2+}**	**Mg^{2+}**	**CEC**	**Al^{3+}**	**H^+**	**AP (ppm)**
Control (0 ml)	0.06 ± 0.00^b	67.46 ± 0.01^a	0.06 ± 0.00^c	0.12 ± 0.00^a	2.94 ± 0.00^d	1.26 ± 0.01^a	8.54^c	-	1.27 ± 0.01^d	59.57^b
100 ml	0.06 ± 0.00^b	66.27 ± 0.00^b	0.07 ± 0.00^b	0.12 ± 0.00^a	2.87 ± 0.00^c	1.26 ± 0.00^a	9.23^b	-	1.44 ± 0.00^c	58.43^b
200 ml	0.07 ± 0.00^a	61.07 ± 0.04^c	0.07 ± 0.00^b	0.12 ± 0.00^a	3.01 ± 0.00^b	1.25 ± 0.00^a	9.34^b	-	1.57 ± 0.01^b	60.26^a
300 ml	0.07 ± 0.00^a	54.94 ± 0.00^d	0.08 ± 0.00^a	0.11 ± 0.00^a	3.33 ± 0.00^a	1.25 ± 0.00^a	9.61^a	-	1.67 ± 0.00^a	61.33^a

*Means with different letters as superscripts along a column are significantly different at $p \leq 0.05$.
Source: Authors

Table 3. Effect of SEO on the heavy metals of the *A. hypogaea* rhizosphere.

Soil treatment	Lead (mg/kg)	Chromium (mg/kg)	Cadmium (mg/kg)	Iron (mg/kg)	Zinc (mg/kg)
Control (0 ml)	0.57 ± 0.00^d	< 0.001	< 0.001	1.66 ± 0.00^d	0.95 ± 0.00^d
100 ml	0.59 ± 0.00^c	< 0.001	< 0.001	1.69 ± 0.00^c	1.34 ± 0.00^c
200 ml	0.62 ± 0.00^b	< 0.001	< 0.001	1.70 ± 0.00^b	1.36 ± 0.00^b
300 ml	1.89 ± 0.00^a	< 0.001	< 0.001	1.73 ± 0.00^a	1.48 ± 0.00^a

*Means with different letters as superscripts along a column are significantly different at $p \leq 0.0$.
Source: Authors

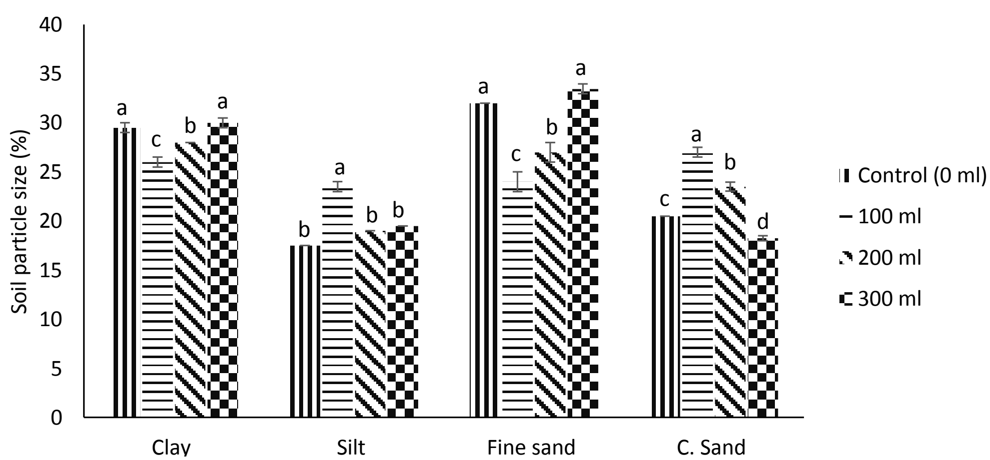

Figure 1. Effect of SEO on the particle size of *A. hypogaea* rhizosphere.
Source: Authors

oil affected the rhizosphere of *A. hypogaea*. SEO raised the percentage of organic carbon and organic matter in the rhizosphere of *A. hypogaea* considerably. This large increase in C and OM in the treated soil compared to the control could be ascribed to soil contamination by the spent engine oil.

This was in line with previous results from researchers who conducted similar investigations and discovered that applying used engine oil to the soil could enhance organic carbon levels (Okonokhua et al., 2007; Nwite and Alu, 2015).

This could be due to contamination caused by the mineral elements present in the oil. In comparison to control, Okonokhua et al. (2007) found an increase in carbon and nitrogen in used lube oil-treated soil. At low pH, metal retention to soil organic matter is less, resulting in more readily available metal in the soil solution for root absorption.

This could also explain why the organic matter in the control soil was lower than in the treated soils (Nwite and Alu, 2015). SEO pollution caused a considerable increase in pH, according to the findings. This contradicts prior claims that SEO pollution lowers soil pH (Okonokhua et al., 2007; Nwite and Alu, 2015). There was no significant variation in pH between control and wasted oil-treated soil, according to Osuji and Nwoye (2007), Okonokhua et al. (2009), and Nwite and Alu (2015). The increase in pH, on the other hand, could indicate that *A. hypogaea* is a good phytoremediator. The variation could be due to interactions between the organisms found in the test plant's rhizosphere and SEO. The root nodules' association with nitrogen-fixing bacteria may have increased remediation efficiency (Ogbo et al., 2009), as evidenced by the high pH values, which were almost neutral to alkaline. According to Desai and Vyas (2008), greater soil pH ranging from 7 to 8 has been found to facilitate optimal microbial breakdown in the environment (Desai and Vyas, 2006). The study found differences in particle size; however, the texture of the sand did not differ between the treatments, according to USDA (2017) classification. All of the samples fell within the sandy clay loamy soil texture category.

According to Agbogidi and Enujeke (2012), SEO did not influence the physical qualities of the soil, but visual examination revealed that plots that got wasted oil (SEO) treatment had less water infiltration and percolation in the soil. When compared to the control, a significant (P 0.05) increase in soil nitrogen and accessible phosphorus was seen at 200 ml and 300 ml concentrations. In contrast, Kayode et al. (2009) found lower nitrogen levels in soil treated with waste lube oil (SEO). The nutrient composition may have been improved as a result of the rhizosphere effect. It could be due to the legume's ability to fix nitrogen. However, some studies have found that applying spent engine oil to soil has a positive effect since it can improve the organic carbon and nitrogen content of the soil (McLaren et al., 2005; Odukoya et al., 2019). This is because, at low pH, many metal cations are more soluble and accessible in the soil solution (Odukoya et al., 2019). The relative quantity and availability of various important nutritional components are indicated by the exchangeable base distribution. For Ca and Mg, a cation concentration of around 2 mg/100g soil is regarded appropriate, whereas, for K, 0.2 mg/100g soil and above is considered adequate. The results revealed that higher SEO concentrations resulted in a considerable rise in CEC. Ca levels were also observed to be greater in SEO-polluted soil.

In comparison to the control, there was an increase in Fe and Zn concentrations in polluted soil. This is in line with the findings of McLaren et al. (2005) and Odukoya et al. 2019), who found that petroleum oil contamination improves soil content with some nutrient elements such as Mg, K, P, Na, Fe, and Zn, and has a substantial impact on plant chemical composition. The potassium and magnesium contents of the polluted soils were found to be lower than the needed values for the cultivation of specific crops, even though there was no significant difference between the contaminated and control samples (Kayode et al., 2009). In the contaminated rhizosphere of the plant, SEO raised the concentration of lead in a dose-dependent manner. The build-up of lead in SEO could be to blame for the increase in Pb content in the treated soil.

This is consistent with the findings of Delorme et al. (2001), who found that SEO becomes contaminated with heavy metals as a result of engine wear and strain. Heavy metals uptake by crops was observed by Adweole et al. (2008), who also noted that these heavy metals were stored in crop parts. The assumption is that heavy metal poisoning poses a threat to humans. According to the findings of Anikwe and Nwobodo (2002) and Asadu et al. (2008), humans are in danger of heavy metal toxicity if they consume foods cultivated in areas polluted with heavy metals due to heavy metals eco-toxicity. This might be conceivable if heavy metals are recycled via the food chain. Lead and cadmium are heavy metals that can harm a person's brain, kidneys, or reproductive system. The uptake of lead by maize grains was often greater than that of cadmium. This shows that eating crops produced on used engine oil-treated soils exposes man to an increased risk of lead poisoning.

Conclusion

As seen in this study, SEO applications generated certain alterations in soil chemistry. SEO application did not negatively alter soil texture, but it did greatly improve soil cation exchange capacity, nitrogen, accessible phosphorus, and other mineral nutrients, according to the study. Despite heavy metal deposition, the groundnut plant's rhizosphere action may have improved the mineral contents of the soil. However, more research is needed to determine the metal uptake by the plant and its potential use in phytoremediation.

CONFLICT OF INTERESTS

The authors have not declared any conflicts of interests**.**

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