Effect of Manure and *Glomus hoi* on Heavy Metals and Soil Properties of Spent Engine Oil Contaminated Soil

ABSTRACT

This study aimed to assesses the impact of spent engine oil on selected soil properties including the heavy metal uptake before and after application of manure. The field experiments were carried in the early cropping season (April – July) and in the late cropping season (September – December) of year 2020 at the Obafemi Awolowo University Teaching and Research Farm, Ile-Ife. Spent-engine oil (SEO) was sourced from a mechanic workshop in Osogbo, Osun State. Amendments (poultry droppings, cow dung and leaves of *Gliricidia sepium)* were collected from OAU Teaching and Research Farm, Ile-Ife. *Glomus hoi* was also collected from around the region, and the spores were isolated through wet sieving methods. The test crop used was maize (variety is AWR- SYN- Y. A land area of 69 m x 17 m was ploughed and harrowed and arranged in an 8 X 6 alpha lattice design, containing sixteen (16) treatments with three concentrations which resulted in a total of forty-eight (48) plots in each replicate, each plot measured 2 m X 2 m with a spacing of 1 m in between the plots. The plots were impacted with Spent-engine oil (SEO) sourced from petrol engines. The oil was applied in concentration of 0 ml (0 L/ha), 400 ml (1000 L/ha) and 800 ml (2000 L/ha) to the plots. The treatments were applied to plots 7 days after Spent-engine oil (SEO) application. The layout of the experiment is as follows: Treatment 1 (T1) - Spent-engine oil only; Treatment 2 (T2) - Spent-engine oil + Cow dung; Treatment 3 (T3) - Spent-engine oil + Poultry Manure; Treatment 4 (T4) - Spent-engine oil + *Glomus hoi*; Treatment 5 (T5) - Spent-engine oil + *Gliricidia Sepium* leaves; Treatment 6 (T6) - Spent-engine oil + Cow dung + Poultry Manure; Treatment 7 (T7) - Spent-engine oil + *Glomus hoi* + *Gliricidia sepium* leaves; Treatment 8 (T8) - Spent-engine oil + Cow dung + Poultry Manure + *Glomus hoi* + *Gliricidia sepium* leaves. After treatments application, the plots were left for two weeks before planting to allow for incubation. Data collected were analyzed using appropriate statistical techniques. At the end of the experiment, all soils were impacted with the presence of increased Spent-engine oil with an increase in heavy metals in the soil. The findings suggest that a combination of different organic amendments can significantly reduce the heavy metal uptake of soils contaminated with spent-engine oil. However, further studies are needed to investigate the long-term effects of these treatments on soil quality and plant growth.

Keywords: organic amendment, spent-engine oil, heavy metals, soil productivity.

1.0 INTRODUCTION

1.1 Background to the Study

Environmental pollution initiated by Spent-engine oil (SEO) is becoming broadly spread than crude oil pollution. Spent-engine oil, which is sometimes referred to as used engine oil, is gotten from either mechanical automotive or electrical engine repair shops [1] after servicing vehicle engines, generating set, and other engine types. The common practice for the disposal of SEO, particularly by motor mechanics in Nigeria are into gutters, water drains, open vacant lands, and farms [2] . Spent-engine oil contains a mixture of different chemical compounds which have been found to be harmful to soil organisms and human health [3].

Spent-oil contaminated soils have been reported to be characterised by nutrients deficiency (nitrogen and phosphorus), inhibition of microbial activities, and degradation of soil physical properties [4]. Oil spills on agricultural land generally reduce plant growth [5] as well as the population of soil microflora and fertility [6].

Bioremediation is a process that utilizes naturally occurring microorganisms to transform harmful substances to nontoxic compounds. These processes take advantages of microbial degradation of organic and inorganic substances by using microorganisms to remove environmental pollutants of soils, water, and sediments [7]. Bioremediation has been globally accepted as a method for treating contaminated soil [8]. The use of arbuscular mycorrhizal fungi has also been reported to aid bioremediation process [9]. Although this technology is yet to evolve in Nigeria, it will invariably prove most useful in the remediation of spent oil polluted soils [10] .

Cow dung, poultry droppings, and *Gliricidia sepium* leaves are major agro-based and organic wastes which are usually ill-managed in the Nigerian environment [11]. However, research has shown that such wastes are effective in modifying the physical and chemical properties of the soil as well as being able to release nutrients for a longer period and helps in the remediation of oil-contaminated soil [12], [13].

Gliricidia sepium is a multipurpose leguminous plant and a potential green leaf manuring crop in which the leaves can increase the yield of several crops due to its high nitrogen content [14]. *G. Sepium* leaves may be adopted to increase soil fertility [15]. Mycorrhiza-assisted remediation (MAR) is a bioremediation aspect that can be used to treat organic as well as inorganic pollutants [16]. *Glomus hoi* is one out of the various arbuscular mycorrhizal fungi that have been reported to aid the treatment of polluted soils and reduce toxic effects of pollutants [17]. Maize is a multifunctional crop due to the economic value of each part of its plant [18]. Studies shown the presence of high levels of some heavy metals in maize and vegetable crops, thereby given rise to a level of apprehension in the consumers [19].

Several research have been carried out on the use of several amendments to recover contaminated soils, but information on the use of combined application of agro-based organic manure and *Glomus hoi* to improve the properties of Spent-engine oil contaminated soils, with a view to making it available for crop production is limited. The objective of this study is to determine the selected properties and heavy metal uptake of spent-oil impacted soil before and after application of manure (cow dung, poultry droppings and *Gliricidia sepium* leaves) and *Glomus hoi*;

2.0 MATERIALS AND METHODS

2.1 Experimental site description

This study was carried out at Obafemi Awolowo University Teaching and Research Farm within the rainforest belt of south-western Nigeria for a period of one year in the year 2020.

2.2 Experimental Materials

Spent-engine oil (SEO) was sourced from Saratu mechanic workshop in Osogbo, Osun State, Nigeria. The predominant engine oil used in the mechanic workshop is Mobil lubricating oil. *Zea mays* variety (AWR- SYN- Y) was obtained from the Maize Breeding Programme of the Department of Crop Production and Protection, Obafemi Awolowo University (OAU), Ile-Ife. Poultry droppings, cow dung and leaves of *Gliricidia sepium* were collected from OAU Teaching and Research Farm, Ile-Ife. The poultry droppings and cow dung were air-dried for three weeks after which it was ground into powdered form. Mycorrhiza (*Glomus hoi*) was collected from the Mycology laboratory and propagated in the Screenhouse of the Department of Crop Production and Protection, OAU, Ile-Ife.

2.2.2 Isolation / Separation of *G. hoi*

Soil from maize plant cultivated with *G. hoi* was collected from around the region, the spores were isolated through wet sieving methods as described by [20]. After thorough mixing, 100 g of each of the samples was weighed and suspended in 250 ml of water in a beaker. It was vigorously stirred and allowed to settle for 10-15 minutes. The suspension was decanted over a series of sieves (75, 63 and 53µm). The process was repeated thrice but the content of the last 2 sieves were collected and suspended in 40% w/v (weight per volume) sucrose gradient solution. The suspension was then centrifuged at 3000 rpm for 5 min [21].The supernatant was decanted into a 38 µm sieve to weigh away the sucrose solution in distilled water. The remaining content was then poured into a grid-line plate for examination and counting under a field (dissecting) stereomicroscope.

2.3 Field Experiment

2.3.1 Field preparations and experimental design

Soil sample was collected and analysed to determine the initial chemical and physical properties of the soil. Plots were tilled in the first year of the experiment and were zero tilled in the subsequent year. A land area of 69 m x 17 m was ploughed and harrowed and arranged in an 8 X 6 alpha lattice design, containing sixteen (16) treatments with three concentrations which resulted in a total of forty-eight (48) plots in each replicate, each plot measured 2 m X 2 m with a spacing of 1 m in between the plots. The experiment was replicated three times. The treatments were applied to plots 7 days after Spent-engine oil (SEO) application. After treatments application, the plots were left for two weeks before planting to allow for incubation. The test crop used was maize (variety; AWR- SYN- Y). The plots were maintained weed-free by manual weeding at 2, 5 and 7 weeks after sowing.

2.3.2 Experimental treatment layout

The layout of the experiment is as follows;

Treatment 1 (T1) - Spent-engine oil only

Treatment 2 (T2) - Spent-engine oil + Cow dung

Treatment 3 (T3) - Spent-engine oil + Poultry Manure

Treatment 4 (T4) - Spent-engine oil + *Glomus hoi*

Treatment 5 (T5) - Spent-engine oil + *Gliricidia sepium* leaves

Treatment 6 (T6) - Spent-engine oil + Cow dung + Poultry Manure

Treatment 7 (T7) - Spent-engine oil + *Glomus hoi* + *Gliricidia sepium* leaves

Treatment 8 (T8) - Spent-engine oil + Cow dung + Poultry Manure + *Glomus hoi* + *Gliricidia sepium* leaves

2.3.2.1 Spent-engine oil (SEO) Application

The plots were impacted with Spent-engine oil (SEO) sourced from petrol engines. The oil was applied in concentration of 0 ml (0 L/ha), 400 ml (1000 L/ha) and 800 ml (2000 L/ha) to the plots. The control plots were protected with asbestos sheets driven to a depth of 30 cm in the soil to prevent contamination of the control plots from adjacent plots with spent oil.

2.3.2.2 Manure Application

Gliricidia sepium leaves, cow dung and poultry droppings were introduced to the plots at (7) days after the oil contamination and allowed to incubate for 14 days, before planting the maize crop. One kilogram (2.5 t/ha) of chopped *Gliricidia sepium* leaves was spread on green manure designated plots in each replicate. The chopped leaves were properly incorporated into the soil. Application of cow dung and poultry manure was done by incorporating 1 kg (2.5 t/ha) of the appropriate manure per designated plots in each replicate. The manure was well stirred to ensure even distribution within the soil.

2.3.2.3 Mycorrhizhal Innoculation and Sowing of Seeds

Mycorrhizal inoculation was done at the time of planting by placing 50 g crude inoculum consisting of spores, hyphae and root fragments of *Glomus hoi* in designated planting holes before sowing seeds. Sowing of seeds was done manually at the rate of two seeds per hole, to depth of 2.5 cm and spacing of 50 cm x 50 cm and thinned down to one plant per stand after sowing.

2.4. Laboratory Analysis

2.4.1. Soil Physicochemical Analysis

Composite surface soil samples (0 – 20 cm) were collected before planting and after harvesting. The samples were air dried at room temperature, crushed and sieved through a 2 mm mesh prior analysis. The following laboratory procedures were carried out to determine some physical, chemical and biological properties of the soil and maize crop.

2.4.2. Soil Particle Size Determination

Particle size distribution was determined using the hydrometer method [22] and [23].The first reading was taken 40 s after the cylinder was set down. The hydrometer was removed, and the temperature of the suspension was taken with a thermometer. The first reading was the percentage of silt and clay in the mixture. The suspension was allowed to stand for 3 hours after which a second hydrometer and thermometer reading were taken. The first reading measures the percentage of silt and clay in suspension while the second reading indicates the percentage of 2µ (total) clay in suspension. The results were expressed as the percentages by weight of sand, silt and clay for all soils analyzed.

2.4.3. Soil pH

Soil pH was determined using official method adopted from [24]. Soil pH was determined in a 1:1 soil to water suspension an electrode pH tester. Twenty grams of air-dried soil was weighed into a 100 ml beaker and 20 ml of deionized water was added place on a stirrer to mix for 30 minutes. The mixture was allowed to stand for 1 hour and stirred occasionally with a glass rod. The electrodes of the pH tester were inserted into the partly settled suspension and the pH measured. The pH meter was calibrated with pH 7.0 and pH 4.0 buffer solution before use and the electrodes were rinsed with deionized water and wiped clean after each reading. The electrodes were rinsed with deionized water and wiped clean after each reading.

2.4.4. Determination of Electrical Conductivity

Electrical Conductivity (EC) was determined using Jenway Conductivity meter 4520 model as described by [29]. 10 g of dry crushed soil sample (< 0.2 mm) of each type were mixed with 50 ml of deionized water in a bottle to make 1:5 ratio (w/v) slurry and the mixtures were shaken thoroughly for complete dissolution of soluble salts. The soil was allowed to settle down and then conductivity cell was inserted to take the readings.

2.4.5. Determination of Total Nitrogen

Total Nitrogen was determined using Macro - Kjedahl method [25]. The amount of nitrogen was determined in the distillate by titrating with 0.01 N HCl until colour changed from green to pink.

2.4.6. Determination of Exchangeable Acidity

Exchangeable acidity was determined by Mclean's titration method after extraction with KCl. 50 ml of KCl extract was pipetted into a 250 ml Erlenmeyer flask and 100 ml distilled water was added. The milliequivalent of acid used was taken as the amount of exchangeable Al while milliequivalent of exchangeable H was calculated from this.

2.4.7. Determination of Organic Carbon and Organic Matter

Organic carbon and organic matter were determined by the method of [26]. The colour of the solution at the beginning was yellow – orange to dark green depending on the amount of unreacted $Cr_2O_7^{2-}$ remaining, which shifted to a turbid grey before the endpoint which then changes sharply to a wine red at the endpoint. A reagent blank was run using the above procedure without soil to serve as control for the experiment. % C and % organic matter were calculated using the equation below:

% Easily Oxidizable Organic C

$$\% \, Organic \, Carbon \, = \frac{(B - S) \times \, M \, of \, Fe^{2+} \times \, 12 \, \times \, 100}{Gram \, of \, soil \, \times \, 4000}$$

Where: B = ml of Fe^{2+} solution used to titrate blank

S = ml of Fe^{2+} solution used to titrate sample

12 / 400- = milliequvalent weight of C in g

To convert easily oxidizable organic C to total C,

Divide by 0.77

To convert total organic matter the following equation was used:

(b)

$$\% \, Organic \, matter \, = \frac{\% \, total \, C \, \times \, 0.7}{0.58}$$

2.4.8. Determination of Exchangeable Bases

Exchangeable bases were discovered by [27] method. Exchangeable cations (Ca, Mg, Na and K) were extracted with 1 N ammonium acetate. In the soil extracts, calcium and magnesium were determined using the Buck Scientific 210 / 211 VGP Atomic Absorption Spectrophotometer (AAS), while sodium and potassium were determined using Genway flame photometer.

2.4.9. Determination of Available Phosphorus

Available phosphorus was determined by ascorbic acid molybdate blue method as described by [28]. The mixture was left for 15 min and P content was determined with a spectrophotometer at 882 µm.

2.5 Heavy Metal Analysis

2.5.1 Heavy Metal Analysis in Soil

Soil extraction for heavy metals was carried out using [30] method. 10 g of each soil samples was placed in a conical flask. One hundred milliliters of the mixture of 10 ml HNO_3, 5 ml $HClO_4$ and 10 ml 6 N HCl, made up to 250 ml with distilled water was added to each soil sample. This was shaken for 30 mins on a reciprocal shaker and filtered through Whatman No. 1 Filter paper. Analysis of the soil extract for Pb, Fe, Zn, Cu and Cd was carried out using atomic absorption spectrophotometer (AAS).

2.6. Statistical Analysis

Results were presented as means ± SEM (standard error of mean). The data was subjected to descriptive and inferential statistical methods. Agronomic data were visualized using Microsoft Excel 2016, while soil data was subjected to analysis of variance (ANOVA) using R programming language.

The difference in treatment means was separated with Least Significance Difference (LSD) at 0.05 probability level.

3.0 RESULT

3.1 Soil Properties before Planting

Table 1: Physico-chemical and Chemical Properties of Experimental Site before Planting

Parameter	Value
pH (1:1soil/water)	5.7
OM (g/kg)	27.55
Total Nitrogen (g/kg)	0.08
Available P (mg/kg)	46.01
ECEC (cmol/kg)	3.32
Available K^+ (cmol/kg)	0.79
Fe (mg/kg)	112.95
Zn (mg/kg)	3.65
Pb (mg/kg)	1.04
Cd (mg/kg)	0.21
Cu (mg/kg)	1.55
Sand (%)	79.72
Silt (%)	10.00
Clay (%)	12.28
Textural Class	Loamy Sand

Note: OM=Organic Matter, P= Phosphorus, ECEC= Effective Cation Exchange Capacity, K= Potassium, Fe= Iron, Zn= Zinc, Pb= Lead, Cd= Cadmium, Cu= Copper.

The table above provided represents the physical and chemical properties of the experimental site prior to planting. The soil pH of 5.7 indicates that the soil is slightly acidic, which may be suitable for certain plant species. The organic matter content of 27.55 g/kg suggests that the soil has a moderate level of organic matter, which is essential for plant growth. Nitrogen, a crucial nutrient for plant growth, has a low level of 0.08 g/kg, which may need to be supplemented with fertilizers. The moderate levels of phosphorus (46.01 mg/kg) and potassium (0.79 cmol/kg) are important macronutrients for plant growth. Exchangeable cations capacity of 3.32 cmol/kg suggests the soil's capacity to hold cations, while the high level of iron (112.95 mg/kg) and moderate levels of zinc (3.65 mg/kg) and copper (1.55 mg/kg) provide essential micronutrients for plant growth.

Additionally, the heavy metal levels (Pb, Cd) are within safe limits. The soil texture is loamy sand, which offers good water-holding capacity and aeration.

3.2 Chemical Properties of Amendments and Spent Oil Engine Used

Table 2: Chemical Properties of Amendments Used

Parameter	Value		
	Cow Dung	**Poultry Manure**	***Gliricidia sepium* Leaves**
pH	8.1	7.9	5.9
OM (g/kg)	30.67	49.82	21.36
Total N (g/kg)	1.12	2.21	3.07
Total P (mg/kg)	0.35	4.82	0.17
C:N	16:1	23:1	4:1
Available K(cmol/kg)	0.25	1.15	1.80
Fe (mg/kg)	2.25	3.25	34.67
Zn (mg/kg)	2.13	0.13	3.14
Pb (mg/kg)	0.64	1.07	0.16
Cd (mg/kg)	0.29	0.07	0.09
Cu (mg/kg)	0.43	1.12	2.24
Ash Content (%)	22.38	45.72	6.55
Moisture content (%)	16.36	10.58	9.89

Note: OM=Organic Matter, K= Potassium, P= Phosphorus, N= Nitrogen, C:N = Carbon to Nitrogen ratio, Fe= Iron, Zn= Zinc, Pb= Lead, Cd= Cadmium, Cu= Copper.

The table above outlines the physical and chemical properties of cow dung, poultry manure, and *Gliricidia sepium* leaves, which were used as amendments at the experimental site. The pH of cow dung and poultry manure is alkaline, with values of 8.1 and 7.9, respectively, while *Gliricidia sepium* leaves have a slightly acidic pH of 5.9. The organic matter content of poultry manure is the highest at 49.82 g/kg, followed by cow dung at 30.67 g/kg and *Gliricidia sepium* leaves at 21.36 g/kg. The total nitrogen content of the amendments is highest *in Gliricidia sepium* leaves at 3.07 g/kg, followed by poultry manure at 2.21 g/kg and cow dung at 1.12 g/kg. The total phosphorus content is highest in poultry manure at 4.82 mg/kg, followed by cow dung at 0.35 mg/kg and *Gliricidia sepium* 0.17 mg/kg. The C:N ratio is highest in cow dung at 16:1, followed by poultry manure at 23:1 and *Gliricidia sepium* leaves at 4:1. The amendments' potassium content is highest in *Gliricidia sep*ium leaves at 1.80 cmol/kg, followed by poultry manure at 1.15 cmol/kg and cow dung at 0.25 cmol/kg. The heavy metal levels in the amendments are within safe limits, and the ash content and moisture content vary among the amendments. Overall, these amendments provide a range of physical and chemical properties that can improve soil fertility and promote plant growth.

Table 3: Chemical Properties of Spent-engine Oil

Parameter	Value
OC (g/kg)	15.51
Total N (g/kg)	6.81
Available P (mg/L)	0.02
Fe (mg/L)	77.15
Zn (mg/L)	18.25
Pb (mg/L)	12.48
Cd (mg/L)	10.51
Cu (mg/L)	14.92

Note: OC=Organic Carbon, P= Phosphorus, N= Nitrogen, Fe= Iron, Zn= Zinc, Pb= Lead, Cd= Cadmium, Cu= Copper.

The table above provides information on the chemical properties of spent-engine oil. The organic carbon (OC) content of the Spent-engine oil is 15.51 g/kg, and the total nitrogen (N) content is 6.81 g/kg. The oil has a low available phosphorus (P) content of 0.02 mg/L. The heavy metal content of the oil is relatively high, with an iron (Fe) concentration of 77.15 mg/L, a zinc (Zn) concentration of 18.25 mg/L, a lead (Pb) concentration of 12.48 mg/L, a cadmium (Cd) concentration of 10.51 mg/L, and a copper (Cu) concentration of 14.92 mg/L. The high levels of heavy metals in Spent-engine oil make it a potentially hazardous material.

3.4 Soil Properties After Planting

Table 4: Mean pH of soil after planting for each season

	1st Season			2nd Season		
Treatments	0ml	400ml	800ml	0ml	400ml	800ml
T1	5.5	4.7	4.5	5.4	4.6	4.4
T2	5.4	5	4.7	5.3	4.8	4.6
T3	5.4	5	4.7	5.2	4.8	4.6
T4	5.5	5.1	4.8	5.4	4.9	4.7
T5	5.5	5.2	4.8	5.4	5	4.8
T6	5.4	5	4.7	5.3	5	4.6
T7	5.5	5.2	4.8	5.4	5	4.7
T8	5.3	4.9	4.6	5.3	4.8	4.5
LSD	0.00051	0.00052	0.00050	0.00068	0.00034	0.00018

The pH values for the different treatments and planting times appear to be relatively consistent across the different planting times, with some minor variations. The mean plant growth values generally decrease as the amount of treatment (in ml) increases for each planting time. The mean pH values for each treatment and planting time combination are significantly different from each other, with a p-value less than 0.05.

Table 5: Mean Organic Matter (%) of soil after each planting

	1st Season			2nd Season		
Treatments	0ml	400ml	800ml	0ml	400ml	800ml
T1	2.42	2.51	2.59	2.46	2.55	2.62
T2	2.53	2.64	2.69	2.56	2.68	2.72
T3	2.57	2.66	2.71	2.6	2.7	2.74
T4	2.52	2.62	2.67	2.55	2.66	2.7
T5	2.56	2.63	2.68	2.59	2.67	2.71
T6	2.64	2.68	2.73	2.67	2.72	2.76
T7	2.62	2.69	2.74	2.65	2.73	2.77
T8	2.81	2.87	2.92	2.84	2.9	2.93
LSD	0.000143	0.000385	0.000101	0.000190	0.000266	0.000133

Table 5 shows the mean organic matter values (%) of soil after each planting season for different treatments and level of spent engine oil concentration. The treatments had a significant impact on the organic matter content of the soil. Treatment T8 had the highest percent of organic matter content when compared to other treatments. It was also observed that treatment T1 had the lowest organic matter content when compared to other treatment. For instance, in the second planting season, it was observed that under 0 ml concentration, T8 had the highest with 2.84 %. This was followed by T6 with 2.67 %. However, T1 had the lowest with 2.46 %. The results also revealed that organic matter increased as the level of spent engine oil increased. In the first season, for instance, T1 was recorded to have 2.42, 2.51, 2.59 % for 0 ml, 400 ml, and 800 ml respectively. This was observed across all planting seasons. The LSD values calculated for each comparison are very small compared to the mean organic matter values, indicating that the observed differences are statistically significant.

Table 6: Mean Total Nitrogen (g/kg) of soil after each planting

	1st Season			2nd Season		
Treatments	0ml	400ml	800ml	0ml	400ml	800ml

T1	0.8	0.87	0.93	0.85	0.94	0.99
T2	1.24	1.32	1.41	1.32	1.43	1.51
T3	1.33	1.42	1.5	1.41	1.53	1.61
T4	1.22	1.36	1.43	1.31	1.45	1.52
T5	1.57	1.65	1.72	1.65	1.74	1.81
T6	1.55	1.64	1.74	1.64	1.75	1.82
T7	1.68	1.74	1.83	1.77	1.83	1.93
T8	1.95	2.03	2.12	2.04	2.13	2.2
LSD	0.000667	0.000558	0.000110	0.000374	0.000112	0.000675

Table 6 shows the Mean Total Nitrogen (g/kg) of soil after each planting season. Across the two planting seasons, there was a general trend of increasing total nitrogen with increasing spent engine oil concentration. In the first season, for instance, T7 had 1.68 1.74 and 1.83 g/kg for 0 ml, 400 ml and 800 ml respectively. The highest mean values were observed in the second planting season. For example, in the first season Treatment T5 under 800 ml had 1.72 g/kg. However, in the second season T5 had 1.81 g/kg. The LSD values for each treatment show that the observed differences between treatments are significant.

Table 7: Mean Available Phosphorus (mg/kg) of soil after planting for each season

	1st Season			**2nd Season**		
Treatments	0ml	400ml	800ml	0ml	400ml	800ml
T1	22.21	23.54	24.12	23.42	24.03	24.98
T2	24.65	25.96	27.31	25.36	27.11	28.92
T3	25.32	26.78	28.54	26.14	27.95	29.03
T4	23.43	25.45	27.64	24.02	25.87	27.07
T5	24.12	25.99	27.16	25.32	27.21	28.97
T6	25.68	27.31	29.34	26.12	28.23	29.36
T7	24.22	25.97	27.22	25.98	27.34	29.42
T8	29.77	31.27	33.24	30.21	31.96	33.05
LSD	0.000622	0.000525	0.000524	0.000282	0.000157	0.000234

Table 7 displays the mean available phosphorus content (mg/kg) of soil after each planting season. The results show that the available phosphorus content of the soil varied across the different planting seasons and treatment concentrations. In the first planting season, the highest available phosphorus levels were observed in treatments T8. In the first season under 0 ml concentration, T8 had the highest with 29.77 mg/kg. This was followed by T6 (25.68 mg/kg) and T6 (25.32 mg/kg). In the second planting season under 400 ml, the highest available phosphorus levels were observed in treatments T8 (31.96 mg/kg), followed by T6 (28.23 mg/kg) and T3 (27.95 mg/kg) respectively. It was observed that higher concentrations of spent engine oil are associated with higher available phosphorus levels in the soil, particularly in treatments T8. For instance, in the second season T2 had 25.36, 27.11 and 28.92 for 0 ml, 400 ml and 800 ml concentrations respectively. However, there is also significant variability across planting seasons, with the second planting season generally showing higher available phosphorus levels than the first planting season. The LSD values reveals that there are significant differences among the treatments and across all seasons.

Table 8: Mean Potassium (cmol/kg) of soil after planting for each season

	1st Season			**2nd Season**		
Treatments	0ml	400ml	800ml	0ml	400ml	800ml
T1	0.77	0.69	0.63	0.75	0.71	0.65
T2	0.85	0.8	0.76	0.82	0.78	0.73
T3	0.86	0.81	0.77	0.83	0.79	0.74
T4	0.82	0.77	0.73	0.79	0.75	0.7
T5	0.83	0.79	0.75	0.8	0.76	0.72
T6	0.89	0.85	0.82	0.86	0.83	0.8
T7	0.84	0.79	0.75	0.82	0.76	0.72
T8	0.98	0.93	0.90	0.95	0.90	0.87
LSD	0.000916	0.000171	0.000757	0.000571	0.000331	0.000220

Table 8 above provides information on the Mean Potassium (cmol/kg) of soil after each planting season. From the table, it can be observed that the mean potassium levels reduced with increasing levels of spent engine oil concentration. For instance, in the first season T8 had 0.98, 0.90, 0.93 mg/kg across the concentrations of 0 ml, 400 ml, and 800 ml respectively. The same was observed in the second season too. It was also observed that T8 had the highest values across all seasons.

Table 9: Mean Copper (mg/kg) of soil after planting for each season

	1st Season			**2nd Season**		
Treatments	0ml	400ml	800ml	0ml	400ml	800ml
T1	1.12	13.24	16.17	1.07	10.28	13.65
T2	1.38	7.28	9.33	1.29	5.35	7.23
T3	1.96	7.86	9.91	1.86	5.93	7.81
T4	1.11	7.04	9.09	1.01	5.09	7.01
T5	2.14	8.04	10.09	2.02	6.11	8.02
T6	2.04	7.91	9.96	1.95	5.96	7.86
T7	2.06	7.93	9.97	1.94	5.99	7.87

T8	2.16	8.06	10.11	2.06	6.12	8.02
LSD	0.000299	0.000452	0.000485	0.000816	0.000522	0.000245

Table 9 presents the mean copper values for different levels of spent engine oil concentration and different treatments across two planting seasons. The ANOVA results showed that both spent engine oil concentration and treatment had a significant effect on mean copper values ($p<0.05$). The results suggest that higher levels of spent engine oil concentration generally resulted in higher mean copper values. In the first planting season, T1 had 1.12, 13.24, 16.17 mg/kg for 0 ml, 400 ml and 800 ml respectively. The same was observed in the second season, where T1 had 1.07, 10.28, 13.65 mg/kg in those level of spent engine oil concentration respectively.

Table 10: Mean Zinc (mg/kg) content of soil after planting for each season

	1st Season			2nd Season		
Treatments	0ml	400ml	800ml	0ml	400ml	800ml
T1	3.45	20.45	27.96	3.15	18.25	25.26
T2	4.61	13.65	16.22	3.65	10.36	14.25
T3	3.77	12.12	15.25	3.25	9.11	13.27
T4	3.35	11.89	14.98	3.05	8.84	12.56
T5	5.23	13.54	16.14	4.26	10.57	14.25
T6	4.92	12.87	15.84	3.96	9.81	13.81
T7	5.06	13.05	15.91	4.11	10.12	13.89
T8	5.24	13.55	16.16	4.21	10.56	14.11
LSD	0.000249	0.000363	0.000660	0.000608	0.000788	0.000172

The results from table 10 suggest that increasing the concentration of spent engine oil in the soil can lead to an increase in the mean zinc content of the soil. It was observed that the mean zinc content of the soil generally increased as the concentration of spent engine oil increased, with the highest mean values observed in the 800 ml treatments across all planting seasons. Under 800 ml, Treatment T1 had high mean zinc values of 27.96 mg/kg and 25.26 mg/kg in the first and second seasons respectively. This was higher when compared to 400 ml for both seasons. The LSD values for the were consistently the lowest, indicating that the differences were statistically significant.

Table 11: Mean Iron content (mg/kg) of soil after planting for each season

	1st Season			2nd Season		
Treatments	0ml	400ml	800ml	0ml	400ml	800ml
T1	105.94	180.26	227.36	98.26	162.36	209.56

T2	108.25	121.25	152.89	102.25	112.52	144.75
T3	110.45	125.35	156.25	104.69	114.25	146.58
T4	100.34	107.89	129.65	93.65	93.26	120.56
T5	124.26	141.36	172.85	115.14	122.47	160.25
T6	112.36	130.56	161.22	106.36	119.47	150.98
T7	118.26	141.26	168.11	110.25	130.22	159.22
T8	115.64	134.25	163.25	107.26	125.74	153.98
LSD	0.000100	0.000176	0.000104	0.000522	0.000713	0.000570

Table 11 shows Mean Iron content (mg/kg) of soil after planting for each season. From the table, we can observe that the mean iron content of soil varied across different treatments and concentrations of spent engine oil. Generally, the addition of spent engine oil to the soil resulted in an increase in the mean iron content of soil, with higher concentrations of spent engine oil resulting in higher mean iron content. Using the first planting season as example, T4 had the lowest mean iron content of 100.34 mg/kg under the 0 ml concentration. But under 400 and 800 ml, T4 had higher iron mean content of 107.89 and 129.65 mg/kg respectively. The LSD values for iron content are relatively small, indicating that there are statistically significant differences between treatments. Based on the ANOVA analysis, the effect of treatment and concentration on mean iron content was significant ($p < 0.05$).

Table 12: Mean Lead content (mg/kg) of soil after planting for each season

	1st Season			**2nd Season**		
Treatments	0ml	400ml	800ml	0ml	400ml	800ml
T1	0.97	12.65	16.24	0.88	9.24	13.55
T2	1.23	6.75	8.69	1.08	4.65	6.54
T3	1.72	7.32	9.26	1.44	5.22	7.24
T4	0.84	6.05	8.11	0.67	4.03	6.12
T5	1.11	6.19	8.22	0.95	4.11	6.18
T6	1.79	7.42	9.45	1.52	5.32	7.35
T7	1.07	6.08	8.15	0.87	4.05	6.14
T8	1.63	7.19	9.14	1.32	5.11	7.11
LSD	0.000477	0.000247	0.000318	0.000322	0.000244	0.000475

Table 12 shows the Mean Lead content(mg/kg) of soil after planting for each season. In general, the lead content of the soil increased with increasing levels of spent engine oil concentration, regardless of the treatment. For example, for Treatment 1, the lead content at 0 ml, 400 ml, and 800 ml of spent engine oil in the first planting season were 0.97 mg/kg, 12.65 mg/kg, and 16.24 mg/kg, respectively. Among the treatments, T1 consistently had the highest lead content in the soil across all levels of spent engine oil concentration and planting seasons. For example, at 800 ml of spent engine oil in the second planting season, the lead content for T1 was 13.55 mg/kg, while the lead content for the other treatments at 800 ml of spent engine oil ranged from 6.12 mg/kg to 7.35 mg/kg during the second planting season. This trend is consistent across all levels of spent engine oil and planting seasons. The highest lead content in the soil was observed in the first planting seasons. For example, the lead content for T1 at 800 ml of spent engine oil was 16.24 mg/kg in the first planting season. This is higher than 13.55 mg/kg recorded for T1 in the second planting season. There were significant differences in the lead content of the soil among the different treatments and levels of spent engine oil concentration. The LSD values indicate that these differences are statistically significant at a high level of confidence ($p < 0.05$).

Table 13: Mean Cadmium content(mg/kg) of soil after planting for each season

	1st Season			2nd Season		
Treatments	0ml	400ml	800ml	0ml	400ml	800ml
T1	0.18	9.47	11.78	0.16	7.45	9.68
T2	0.42	3.64	5.54	0.34	2.54	4.44
T3	0.22	3.36	5.26	0.18	2.35	4.16
T4	0.17	3.29	5.19	0.14	2.25	4.11
T5	0.24	3.41	5.31	0.21	2.43	4.21
T6	0.49	3.78	5.68	0.39	2.68	4.58
T7	0.23	3.38	5.28	0.19	2.29	4.19
T8	0.41	3.64	5.54	0.33	2.54	4.44
LSD	0.000172	0.000215	0.000291	0.000102	0.000285	0.000452

The cadmium content of the soil generally increases as the concentration of spent engine oil increases. Treatment 1 (T1) consistently had the highest cadmium content in the soil, regardless of the planting season. Across all treatments and seasons, the highest cadmium content was observed in T1. For example, T1 under 800 ml SEO concentration in the first planting season had 11.78 mg/kg of cadmium, while the lowest cadmium content was observed in T4 with 5.19 mg/kg during the same season. Treatment 6 (T6) also had relatively high cadmium content in both seasons compared to treatments T2, T3, T4, T5, T7, and T8. The cadmium content of the soil tends to vary across seasons from the 1st to the 2nd planting season. The LSD values for cadmium content are generally smaller, indicating a higher level of statistical significance. The LSD values for cadmium content ranged from 0.000102 to 0.000452.

5.0 DISCUSSION

Soil amendments such as cow dung, poultry manure, *Glomus hoi* and *Gliricidia sepium* leaves provide numerous benefits for soil health and plant growth. The organic matter, beneficial soil microbes, and plant residues in these amendments will help enhance nutrient availability, while also promoting the microbial activity. [31] stated in their study that cow dung and poultry manure have a potential to add organic matter to the soil, which can improve soil structure, increase soil porosity, and enhance water and nutrient retention. This is due to its high organic matter content. This study observed that cowdung and poultry manure also have high percent of organic matter. This agrees with [32], who also observed a high percent of organic matter in both amendments when analysed. This high organic matter content can help mitigate the negative effects of spent engine oil on soil properties and improve overall soil health [33]. The addition of *Glomus hoi*, a beneficial soil fungus, can also enhance the soil microbial activity and nutrient cycling [34]. This can help to overcome nutrient deficiencies caused by spent engine oil in the soil [35]. The presence of *Glomus hoi* can also enhance the breakdown of PAHs, which are a class of contaminants found in spent engine oil [36]. *Gliricidia sepium* leaves are a good source of nitrogen, which can be beneficial for plant growth [37]. This study observed that *Gliricidia sepium* leaves had a higher percent of total nitrogen (g/kg) when compared to other amendments. This agrees with [38] , who observed a higher percent of nitrogen content (0.67 %) when compared to farmyard manure (0.54 %). The addition of *Gliricidia sepium* leaves to the soil can also enhance nitrogen fixation by soil microorganisms, which can increase the availability of nitrogen for plant uptake [39].

Spent engine oil contains a variety of heavy metals, such as lead, zinc, cadmium, and copper, which can be released into the environment when the oil is improperly disposed of or spilled [40]. This study observed an increase in heavy metal content in spent engine oil polluted soils. This agrees with the observations of [41] who also observed an increase in the heavy metal content (Cd, Cu and Pb) of soils contaminated with spent engine oil. The increased level in the heavy metals observed in the soil could be attributed to the high level of heavy metals in the spent engine oil. Heavy metals are also more available in acidic soils than in neutral or alkaline soils [42].

It was observed that spent engine oil lowered the pH of soil compared to soils with spent engine oil contamination. [43] also observed in his study that spent oil reduced the pH of soil. This could be attributed to the release of heavy metals such as lead, cadmium, and aluminum which can increase soil acidity by releasing hydrogen ions (H+) and reducing pH values [44].

Spent engine oil contains high levels of organic compounds [45]. This could be responsible for the increase in the organic matter content observed in soils contaminated with spent engine oil. [46] also observed an increase in the organic matter of the soil contaminated with spent engine oil. Organic matter is a source of nitrogen for plants and microorganisms. As the organic matter decomposes, it releases nitrogen into the soil in the form of ammonium ($NH4^+$) and nitrate ($NO3^-$) ions [47]. Therefore, soils contaminated with spent engine oil may have increased total nitrogen content due to the increased organic matter content observed in the soil. This was observed in this study where soils treated with spent engine oil had a higher total nitrogen when compared to control soils.

Also, spent engine oil contamination can increase the growth of nitrogen-fixing bacteria in soil, which can increase the total nitrogen content. This can occur because the organic compounds in spent engine oil can provide a source of carbon and energy for these bacteria. This corroborates with the study conducted by [48] when he conducted an experiment on vermiremediation of engine oil contaminated soil employing indigenous earthworms, *Drawida modesta* and *Lampito mauritii*. He observed an increase in the total nitrogen of soils contaminated with used engine oil.

The study also observed an increase in available phosphorus but lower potassium in spent engine oil contaminated soils. [49] also observed the same in his study of biodegradation of spent automobile engine oil in soil microcosms amended with cow dung. Increase in the organic matter content of soil can also contribute to higher levels of available phosphorus. Organic matter in soil can release phosphorus into the soil through mineralization. Spent engine oil contains organic acids that can lower the pH of the soil. This can result in lower potassium levels in the soil [50].

Conclusion

The results of the study have shown that soil contamination with spent-engine oil can alter the physicochemical properties of the soil and degrade its capacity to provide suitable medium for plants growth. However, this study revealed that the combination of each amendment has an ameliorating effect on the spent-engine-oil contaminated soils. The use of soil amendments such as cow dung, poultry manure, *Glomus hoi*, and *Gliricidia sepium* leaves help improve the soil properties of soils contaminated with spent engine oil. Thus, the combination of each soil amendments can be a useful strategy to improve soil health and increase maize productivity in soils contaminated with spent engine oil. However, further research is needed to investigate the effects of these amendments on remediation of soils contaminated with spent engine oil concentration.

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