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Spent engine oil and industrial effluent induced heavy metals and changes in soil and air potato quality

Adesina Femi Peter
Department of Biology, Federal University of Technology Akure, Ondo State, Nigeria
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Abstract

This study was conducted to investigate the effects of spent engine oil and industrial effluent on the soil and Dioscorea bulbifera plant. Spent engine oil (SEO) was added to the buckets filled with 15 kg of loamy soil at different volumes of 0 , 75 , 225, and 375mL. Another bucket was filled with 15 kg of industrial effluent (IE). The results showed that SEO in soil has highly significant ($p \leq 0.05$) effects on some of the soil's physicochemical properties. Industrial effluent (IE) had the highest nitrogen content (0.89%) while the lowest was in 75 mL15kg^{-1} (0.72%). pH was higher in control (4.29) and the lowest was at 375 mL15kg^{-1} (4.89). The chlorophyll content range was 274.06 mg g^{-1} (IE) – 349.60 mg g^{-1} (control). Also, bulbils from IE had the least fresh and dry weight (20.21 g and 14.73 g, respectively). The bioaccumulation factor (BAF) of all heavy metals examined was less than 1, except for copper. Heavy metal uptake order by the bulbil is Cu > Fe > Zn > Pb. Considering the detrimental effects of SEO and IE pollution on soil and plants, it has become necessary for the government to have a policy that will prevent indiscriminate disposal of waste.

Keywords: Bioaccumulation, contamination, *Dioscorea bulbifera*, spent engine oil, heavy metals

Introduction

Environmental pollution is a prominent challenge in the world, in both developed and developing countries (Ukaogo *et al*., 2020). Besides what normally occurs, human activities are contributing tremendously to environmental alteration and contamination. Even advancements in science and technology seem to contribute to pollution in the environment, although they have also provided ways to prevent or remediate pollution in the environment. The aforementioned incident has been detrimental to the environment, resulting in ecosystem imbalance, biodiversity loss, and food scarcity. Environmental pollution is caused by the direct and indirect emissions of hydrocarbon oil, pharmaceuticals, industrial and domestic effluents, agricultural wastes, waste gases, and technological devices (Oyareme *et al*., 2020). Human exposure to pollution is of public health concern, and different international health bodies such as the World Health Organization (WHO) and the Sustainable Development Goals (SDGs) are raising awareness about it.

Soil has been described as a "universal sink" (Muhammad *et al*., 2014) that accommodates several environmental problems globally (Fan *et al*., 2017). Soil reaction, aeration, porosity, humus content, pH, salinity, nutrients (nitrogen, phosphorus, and potash), leaching, and the addition of heavy metals are all physical and chemical changes brought on by soil pollution (Muhammad *et al*., 2014).

The addition of heavy metals to the soil is now of serious concern because of their transfer to plants. Heavy metals have been reported to cause disruption of plant metabolic functions, oxidative stresses, lower essential metal availability, and alter growth performance and yield (Kalavrouziotis *et al*., 2012; Adesina and Ashamo, 2019; Alessio and Luigi, 2020). Any metals or metalloids having an atomic density greater than 5 g/cm^3 are heavy metals (Ali and Khan, 2018), such as copper, zinc, silver, iron, the platinum group, mercury, silver, chromium, lead, and arsenic (Onakpa *et al*., 2018).

Heavy metals are introduced to the soil through parent rocks and anthropogenic activities. Mining, seepage from landfills, pesticide application, industrial effluents, and irrigation of soil with industrial and municipally treated water are other sources of heavy metals (Mahmoud and Ghoneim, 2016; Rahimi *et al*., 2017; Abiya *et al*., 2018). Inadvertent disposal of spent engine oil or used lubrication oil into the soil environment by motor and generator

***Email:** femi.adesina@outlook.com
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mechanics (Agbogidi and Ilondu, 2013; Uchendu and Ogwo, 2014), farm machine users, and private and commercial drivers has also contributed to the heavy metals pool.

In order to evaluate the effects of heavy metals on plants, the air potato plant (*Dioscorea bulbifera*) will be studied. It is a species of yam (Figure 8) that is not well known as a staple food among people; it's only a preference during times of food scarcity. Nevertheless, its medicinal uses are popular among local dwellers (Barnali, 2015). It is described as an invasive and aggressive plant that can outgrow and survive in harsh environments (Osuagwu *et al*., 2013; Celestine and David, 2015). Thus, the aim of this study is to investigate the effect of heavy metals from spent engine oil and industrial effluent on the physiochemical properties of soil and the yield of air potato plant.

Materials and Methods

Experimental site

The study was carried out at the Federal University of Technology, Akure, Ondo State, in the south-west of Nigeria. The Federal University of Technology, Akure is located at latitudes 07° 16^{I} and 07° 18^{I} N and longitudes 05^{0} 09^{I} and 05^{0} 11^{I} E. It is a rainforest zone, with two distinct seasons (the rainy and dry seasons), loamy soil, atmospheric temperature of 28 ^{o}C – 31 ^{o}C, annual rainfall (1524 mm) and annual relative humidity of 80%.

Tubers of air potatoes **(***Discorea bulbifera*) were obtained directly from the farm. While industrial effluents (IE) were collected from the dumpsite of a cocoa processing factory and spent engine oil (SEO) was collected from a mechanic village in Akure, Ondo State, Nigeria.

Methodology

In this study, spent engine oil and industrial effluent were the two treatments. A 30 cm perforated plastic bucket was filled to ¾ of its height with 15 kg of loamy soil. Then spent engine oil of volumes 0, 75 225 , and 375 mL was thoroughly mixed with each experimental pot separately. Another bucket was filled with industrial effluent soil collected from a dump site used by the cocoa industry. All the treatments were replicated three times. Prior to planting, the soil samples were allowed to absorb the spent engine oil for one week. The pots were arranged in a completely randomized design (CRD). The physicochemical analysis was carried out on soil samples before and after contamination. Following that, the same size (25 g) of *D. bulbifera* L. bulbil was planted on each treatment, while watering and staking were carried out as needed. Another set of similar experiment units was set up without planting D. bulbifera in them. This is to determine whether the plant actually removes heavy metals from the pots or if it is only a result of environmental factors.

Determination of chlorophyll content

The chlorophyll content was determined as described by Bamidele and Sijuade (2012). The leaf chlorophyll was extracted from 1.0 g of leaf sample with 10 mL of aqueous acetone. Twenty five (25) mL extract was transferred to ether, and the optical density at 663 nm and 645 nm in 1 cm cells was measured using ether as a reference. Chlorophyll content (mg g^{-1}) was measured using a spectrophotometer.

$$\text{Total Chlorophyll (mg/g)} = [20.2A + 8.02B][V/10W]$$

A = Optical density at 645 nm
B = Optical denity at 663 nm
V = Volume of the sample (mL)
W = Fresh weight of the sample (g)

Determination of fresh weight

The weight (g) of tubers harvested was assured using an Ohaus analytical balance.

Determination of dry weight

The dry weight of the harvested tubers was assured by drying the harvested bulbils in a drying cabinet at 150 ^{0}C for 24 hours. The dried tuber was weighed using an Ohaus analytical balance.

Laboratory studies

Soil pH

Fifty grams (50 g) air-dry soil (2 mm) was weighed into a 100 mL glass beaker, and 50 mL distilled water was added using a graduated cylinder or 50 mL volumetric flask. It was well mixed with a glass rod, and allowed to stand for 30 minutes. During this period, the suspension was stirred every 10 minutes and then left to stand for 1 hour. The pH meter was thoroughly washed (Coleman's pH meter) with water, and it was calibrated with BDH pH 7.0 Buffer tablet solution.

The Combined Electrode was put in suspension (about 3 cm deep) and the reading was taken after 30 seconds, without stirring, and the pH value was recorded. The Combined Electrode was removed, rinsed thoroughly with distilled water in a separate beaker, and the excess water was carefully dried with a tissue.

Soil moisture content

Soil samples were weighed using an analytical balance and dried in an oven at 110 °C for 24 hours. The dried soil samples were cooled to room temperature and weighed again.

The moisture content of the soil samples was calculated by the following equation.

$$\text{Soil Moisture Content (\%)} = ((\text{Wb} - \text{Wa}))/(\text{Wb}) \text{ X } 100$$

where

Wb = Weight of the soil before being dried/wet soil's weight

Wa = dry soil's weight

Total Phosphorus in Soil

Phosphorus (P) analysis was carried out by the BrayP-1 method (Lumbanraja *et al*., 2017).

Determination of the soil nitrogen

The determination of nitrogen (N) was done using the kjeldahl procedure (FAO, 2021).

Calcium (Ca) and magnesium (Mg) were determined using an Atomic Absorption Spectrophotometer (AAS). Sodium (Na) and potassium (K) were determined using a flame photometer.

Soil heavy metals

A sample (10 kg) was processed for analysis by the dry-ashing method. The ground solid samples (5 g each) were placed in crucibles, and a few drops of concentrated nitric acid were added to the solid as an ashing aid. The dry ashing process was carried out in a muffle furnace by gradually increasing the temperature up to 550 °C and then leaving it to ash for 4 hours at this temperature. The ash was left to cool and then rinsed with 1M nitric acid. The ash suspension was filtered, and the filtrate was made up to a volume of 100 mL with 1M nitric acid. Zinc (Zn), Copper (Cu), Iron (Fe) and Lead (Pb) were determined using Atomic Absorption Spectrophotometer (AAS) buck scientific 210 VGP.

Bulbil heavy metals

An air potato bulbil was peeled and thoroughly washed with distilled water to remove any impurities using the method described by Udosen *et al*. (2016). It was ground into smaller pieces, oven dried at 50 – 60 °C and then further ground into powder. One (1) gram of ground air potato flour was weighed into a crucible and placed for 4 hours in a furnace at 500-700 °C. After cooling the ash, it was leached with 5 cm^3 of 6 M HCI and transferred to a 20 cm^3 conical flask; the volume was made up to 20 cm^3 with distilled water. Heavy metals were determined using Atomic Absorption Spectrophotometer (AAS) buck scientific 210 VGP.

The bioaccumulation factor (BAF) was calculated as the ratio of heavy metal (copper, iron, lead, and zinc) concentrations in a plant's bulbil to those in the corresponding soil.

$$\text{BAF} = (\text{Concentration of Heavy Metal in Bulbil})/(\text{Concentration of Heavy Metals in Soil})$$

Statistical Analysis

Data taken on leaf chlorophyll, physicochemical properties, and heavy metals were analyzed using analysis of variance (ANOVA), and means were separated using Duncan's New Multiple Range Test (DNMRT) at the 5% level of significance using SPSS 21.0 software.

Results and Discussion

Analysis of the Spent Engine Oil for the presence of some Heavy Metals

Heavy metals such as iron, lead, zinc, and copper were observed to be present in the spent engine oil (SEO), with zinc having the highest quantity of 6.51 mg kg^{-1} and lead having the lowest amount of 0.21 mg kg^{-1}, as shown in figure 1. The presence of these heavy metals in spent engine oil is also confirmed by Ugwu *et al***.** (2023), but the quantity reported is higher than what this study detected. The amount of heavy metals present in spent engine oil varies depending on whether the engine oil was used in an automobile or a generator.

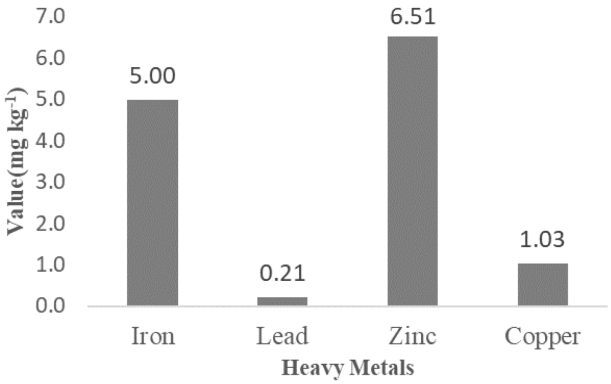

Figure 1: Heavy metals in the spent engine oil

Initial physicochemical characteristics of soil

Table 1 shows the physicochemical properties of the soil before contamination with SEO and industrial effluent . The soil sample type was loamy and contained 71.1% sand, 21.2% silt, and 7.7% silt. The pH of the soil was 4.29, with a phosphorus level of 0.18 mg kg^{-1}, 0.85% nitrogen, and a

Table 1: Physicochemical properties of soil before and after treatment

Parameter	Before	After treatment			
		75 mL 15kg^{-1}	225 mL kg^{-1}	375 mL 15 kgl^{-1}	IE
Soil type	Loamy	Loamy	Loamy	Loamy	Effluent
Sand (%)	71.1	69.9	71.1	70.1	32.4
Silt (%)	21.2	20.5	21.0	21.2	13.1
Clay (%)	7.7	7.7	7.9	7.7	10.0
Moisture Content (%)	10.22	10.12	10.31	10.25	10.14
pH	4.29	4.31	4.50	4.89	4.82
Organic Carbon (%)	4.00	5.60	8.00	8.02	4.60
Organic Matter (%)	6.90	9.65	13.79	13.82	7.93
Calcium (cmol kg^{-1})	4.50	1.50	2.50	2.50	4.50
Magnessium (cmol kg^{-1})	1.50	3.10	2.50	1.50	1.30
Phosphorus (mg kg^{-1})	0.18	0.31	0.18	0.16	0.14
Nitrogen (%)	0.85	0.72	0.91	0.98	0.89
Sodium (cmol kg^{-1})	34.40	42.50	43.60	37.80	38.50
Potassium (cmol kg^{-1})	21.40	22.80	23.30	36.20	21.50
Iron (mg kg^{-1})	11.00	10.00	8.00	12.80	4.59
Lead (mg kg^{-1})	0.20	0.60	0.70	0.70	0.10
Zinc (mg kg^{-1})	2.04	2.20	2.40	7.09	2.92
Copper (mg kg^{-1})	0.07	0.39	0.28	0.30	0.76

sodium content of 34.4 mg kg^{-1}. It had a high amount of iron (11.0 mg kg^{-1}) and a low amount of copper (0.07 mg kg^{-1}) as heavy metals. The physicochemical properties of the soil contaminated with different concentrations of SEO and the soil from the industrial effluent (IE) were different from the properties of the soil before contamination. The soil with 375 mL 15kg^{-1} SEO had the highest pH value of 4.89 while IE had a pH value of 4.82. After intentional contamination, the pH was lowered (there was 0.5 – 13.9% increment in value) by making the soil less acidic. Uhegbu *et al.* (2012) and Nwite and Alu (2015) found similar results, demonstrating that adding spent engine oil (SEO) to soil made it less acidic. In contrast, observations from Achuba and Peretiemo-Clarke (2008) and Obazuaye and Obueh's (2014) study show that SEO in the soil makes it more acidic. This disparity may be due to the soil type used in the study and the presence of microorganisms that can metabolize organic acid. Typically, acidic soil (in the right quantity) is better for plant growth than neutral or alkaline soil because it makes micronutrients available (Lonˇcari *et al*., 2008; Gentili *et al*., 2018). However, the slightest changes in pH value due to SEO are not significantly different from the control studied. Lekshmi and Rajani (2017) and Mbangi *et al*. (2018) also confirmed that industrial effluent (IE) altered the soil pH, which might be due to soluble salts present in IE.

Industrial effluent (IE) had the lowest organic carbon content of 4.6, and for the SEO treatment, the organic carbon increased as the concentration of SEO increased. Organic carbon increases by 15% - 101% and organic matter rises by 14.9% - 100.3% in the oil contaminated soil. It is anticipated that when spent engine oil contamination increases, the total hydrocarbon content of the soil will rise. Since carbon and hydrogen make up the majority of SEO, carbon can be easily added into the soil when contaminated with SEO. This finding supported the significant increase in soil organic carbon observed by Osaigbovo *et al*. (2013) and Nwite and Alu (2015) following the addition of SEO to the soil. Furthermore, the amount of magnesium and phosphorus decreased as the SEO concentration increased in the soil. Meanwhile, the amount of potassium increased as the concentration of SEO increased, and the IE had the lowest amount of potassium (21.50 mg kg^{-1}).

The addition of SEO to the soil seemed to have increased the total nitrogen in the soil when compared with the physicochemical properties of the soil before adding SEO. The highest total nitrogen was in 375 mL 15kg^{-1} (0.98%), followed by 225 mL 15kg^{-1} (0.91%), IE (0.89%), and the least was in 75 mL 15kg^{-1} SEO contaminated soil (0.72%). It was observed that potassium and calcium in the soil decreased while nitrogen increased with SEO treatments. There was a slight difference in the quantity of lead (Pb) added to the soil as the concentration of SEO increased, but IE has a small amount (0.1 mg kg^{-1}) of lead present. However, IE has much more zinc (2.92 mg kg^{-1}) than 75 mL15kg^{-1} (2.2 mg kg^{-1}) and 225 mL 15kg^{-1} (2.4 mg kg^{-1}) of SEO in the soil. With the addition of SEO, heavy metals in the soil rise. This is

Table 2: Physicochemical properties of soil after 16 weeks of planting

	MC	pH	OC	OM	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})	P (mg kg^{-1})	N (%)	Na (mg kg^{-1})	K (mg kg^{-1})	Fe (mg kg^{-1})	Pb (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})
Control	10.35^{a} ±0.57	4.08^{ab} ±0.01	3.89^{b} ±0.06	6.71^{d} ±0.01	4.40^{a} ±0.05	1.70^{ab} ±0.23	0.19^{a} ±0.01	2.10^{a} ±0.23	29.50^{c} ±0.29	18.60^{e} ±0.12	6.80^{b} ±0.12	0.13^{c} ±0.01	1.90^{b} ±0.06	0.04^{c} ±0.01
A	10.56^{a} ±0.57	4.00^{b} ±0.11	5.00^{b} ±0.58	8.62^{c} ±0.36	2.10^{c} ±0.17	1.91^{a} ±0.01	0.17^{ab} ±0.02	0.81^{c} ±0.05	33.00^{b} ±0.87	22.01^{c} ±0.01	7.00^{b} ±0.12	0.25^{b} ±0.03	2.00^{b} ±0.29	0.20^{b} ±0.01
B	10.51^{a} ±0.79	4.13^{ab} ±0.06	7.20^{a} ±0.46	12.22^{b} ±0.22	2.78^{b} ±0.02	1.23^{c} ±0.05	0.18^{a} ±0.01	0.69^{c} ±0.03	36.13^{a} ±0.08	24.50^{b} ±0.29	7.90^{a} ±0.06	0.57^{a} ±0.02	2.00^{b} ±0.12	0.23^{b} ±0.06
C	11.98^{a} ±2.25	4.58^{ab} ±0.08	7.82^{a} ±0.58	13.48^{a} ±0.23	2.50^{bc} ±0.23	1.61^{ab} ±0.11	0.12^{c} ±0.01	0.71^{c} ±0.06	36.67^{a} ±0.04	30.02^{a} ±0.01	8.57^{a} ±0.13	0.54^{a} ±0.02	2.86^{a} ±0.04	0.26^{b} ±0.03
D	13.51^{a} ±0.04	4.80^{b} ±0.46	7.90^{a} ±0.06	13.62^{a} ±0.11	4.25^{a} ±0.14	1.35^{bc} ±0.03	0.13^{bc} ±0.01	1.21^{b} ±0.06	32.40^{b} ±0.23	20.15^{d} ±0.09	4.00^{c} ±0.56	0.11^{c} ±0.02	2.16^{b} ±0.06	0.53^{a} ±0.01

The means ± standard error represent three (3) replicates. Means having the same alphabet down the column are not significantly different from one another using Duncan's New Multiple Range Test (DNMRT) at $p > 0.05$.

Key: A – 75 mL 15kg^{-1}, B – 225 mL15kg^{-1}, C – 375 mL 15kgl^{-1}, D – Industrial effluent, OM – Organic Matter Mg – Magnesium, K – Potassium, Cu – Copper, B – 225mL 15kg^{-1} of soil, OC – Organic Carbon, P – Phosphorus, Fe – Iron, MC – Moisture Content, N – Nitrogen, Pb – Lead, D – Industrial effluent, Ca – Calcium, Na – Sodium, Zn – Zinc.

attainable as a result of the fact that brand-new engine oil runs through numerous machine engine components and then absorbs other metals and dirt to become SEO. Likewise, industrial effluent has more copper than other treatments and more zinc than 75 mL 15kg^{-1} and 225 mL 15kg^{-1} SEO. Industrial effluent is a combination of several waste materials, both liquid and solid, that are or have absorbed toxic gases and metals. Spent engine oil and IE will therefore introduce their contents into the soil environment when being disposed indiscriminately or not properly treated. This result showed that soil qualities like nitrogen content, pH, carbon, the presence of trace heavy metals, and even its physical appearance are significantly impacted by spent engine oil or industrial effluent.

The visual observation showed that the pots that received spent engine oil treatment reduced water infiltration and percolation in the soil. This caused water to collect into little pools, which later lengthened the time needed for infiltration by 80%. On drying, the soil took on a little solid waxy appearance that more or less repelled or resisted water rewetting. This observation is in harmony with earlier reports by Agbogidi and Egbuchua (2010), who noted that hydrocarbon oil in soil has deleterious effects on the physical properties of the soil depending on the concentration and type of the oil.

Physicochemical properties of soil after 16 weeks of planting

Table 2 shows the physicochemical characteristics of the control soil and contaminated soil (SEO and IE) after 16 weeks of planting *D. bulbifera***.** There was no significant difference (p>0.05) between the control and other levels of treatments in their moisture content and pH level. Organic carbon of control (3.89%) and 75 mL 15kg^{-1} (5.00%) were not significantly different, but they were significantly different from 225 mL15kg^{-1} (7.20%), 375 mL 15kg^{-1} (7.82%) and IE (7.90%). In organic matter level, there was no significant difference between 375 mL15kg^{-1} (13.48%) and IE (13.62%), while IE had the highest level of organic matter. The highest calcium (Ca) level was in the control (4.40 cmol kg^{-1}). Control (4.40 cmol kg^{-1}) was not significantly different from IE (4.25 cmol kg^{-1}) and also 375 mL 15kg^{-1} (2.50 cmol kg^{-1}) not significantly different from 225 ml 15kg^{-1} (2.78 cmol kg^{-1}) and 75 mL15kg^{-1} (2.10 cmol kg^{-1}).

The magnesium levels in the control (1.7 cmol kg^{-1}), 75 mL 15kg^{-1} (1.91 cmol kg^{-1}), and 375 mL 15kg^{-1} (1.61 cmol kg^{-1}) were not significantly different ($p > 0.05$) from one another, while the highest magnesium level was in 75 mL15kg^{-1}. There was no significant difference between the phosphorus (P) level of the control (0.19 mg kg^{-1}), 75 mL15kg^{-1} (0.17 mg kg^{-1}) and 225 mL kg^{-1} (0.18 mg kg^{-1}); meanwhile, 375 mL 15kg^{-1} (0.12 mg kg^{-1}) was not significantly different from IE (0.13 mg kg^{-1}). Nitrogen increased in 0 mL 15kg^{-1}, 75 Ll 15kg^{-1}, and IE, but the highest concentration of nitrogen was in the control (2.10%), and it was significantly different from other treatments. Recently, nitrogen-fixing bacteria have also been identified in some yam species apart from leguminous crops (Rezaei *et al*., 2017; Takada *et al*., 2018; Ouyabe *et al*., 2020). If this is possible with *D. bulbifera*, the decrease in nitrogen content of the contaminated soil suggests that the presence of SEO or IE may have altered

how the bacteria that fix nitrogen for *D. bulbifera* behaved. Concentration 375 mL15kg^{-1} (36.67 mg kg^{-1}) contains more sodium (Na) but is not significantly different from 225 mL 15kg^{-1} (36.13 mg kg^{-1}). In potassium (K), a significant difference exists among the treatment levels, with the control (18.6) having the least amount and 375 mL15kg^{-1} (30.02 mg kg^{-1}) having the highest.

The iron (Fe) concentration of IE (4.0 mg kg^{-1}was significantly different from others, while control (6.80 mg kg^{-1}) and 75 mL15kg^{-1} (7.00 mg kg^{-1}were significantly different from 225 mL15kg^{-1} (7.90 mg kg^{-1}) and 375 mL15kg^{-1} (8.57 mg kg^{-1}). Control (0.13 mg kg^{-1}) and 1E (0.11 mg kg^{-1}) were not significantly different in the lead (Pb) concentration. In zinc (Zn), 375 mL15kg^{-1} (2.86 mg kg^{-1}) has the highest amount, and it was significantly different from another level of treatment. Concentrations of 75 mL15kg^{-1} (0.20 mg kg^{-1}), 225 mL15kg^{-1} (0.23 mg kg^{-1}), and 375 mL15kg^{-1} (0.26 mg kg^{-1}) were not significantly different in copper concentration but significantly different from control (0.04 mg kg^{-1}) and IE (0.53 mg kg^{-1}). Industrial effluent (IE) recorded the highest amount in copper level using Duncan's New Multiple Range Test (DNMRT) at $p > 0.05$. It was also noted that potassium increased in the uncontaminated soil, while heavy metals were observed to decrease in the contaminated soil, after 16 weeks of planting *D. bulbifera*. This shows that heavy metals have been absorbed into the plant parts.

Heavy Metals in contaminated soil with and without *D. bulbifera* plant

A contaminated soil with an air potato plant (CW) was compared with a contaminated soil with no air potato plant (CWO) on it under the same environmental conditions for 16 weeks. There was a significant difference in the iron (Fe) level of CW and CWO in 75 mL15kg^{-1} and 375 mL15kg^{-1}, but no significant difference among the others, while CWO (9.33 mg kg^{-1}) had the highest level of iron when compared to CW (7.13 mg kg^{-1}) in 75 mL kg^{-1}. In 75 mL 15kg^{-1}, CW (0.25 mg kg^{-1}) was significantly different from CWO (0.73 mg kg^{-1}) but there was no significant difference in 225 mL15kg^{-1} or 375 mL 15kg^{-1}. Industrial Effluent (IE) shows a significant difference in lead concentration between CW (0.11 mg kg^{-1}) and CWO (0.34 mg kg^{-1}). Zinc levels differed significantly between CW and CWO by 75 mL 15kg^{-1}, 225 mL15kg^{-1}, and 375 mL 15kg^{-1}. In IE, there was no significant difference between CW (2.1 mg kg^{-1}) and CWO (2.0 mg kg^{-1}). CWO (0.30 mg kg^{-1}) was significantly different from CW (0.20 mg kg^{-1}) in their level of copper in 75 mL15kg^{-1}, but there was no significant difference in 225 mL 15kg^{-1}, 375 mL 15kg^{-1}, and IE, using Duncan's New Multiple Range Test (DNMRT) at $p > 0.05$.

It was observed that heavy metals like iron, zinc, and copper were significantly reduced in CW when compared with CWO. Except in IE, where CWO has less iron, zinc, and copper than CW, this is also evidence that plants may absorb heavy metals from the soil. Absorption of heavy metals by other plants planted in polluted soil has been reported by other researchers. Rahimi *et al*. (2017) reported heavy metals in rice plant parts collected from paddy fields in Lenjan, southwest Isfahan Province, central Iran. Likewise, Odiyi *et al*. (2020) reported heavy metal content in maize plants planted on crude oil-polluted soil, and Usman *et al*. (2019) also reported bioaccumulation of heavy metals in a shrub plant (*Tetraena qataranse*) in Qatar.

This study also suggests that *D. bulbifera* might have the ability to remediate soil contaminated with hydrocarbon oil. The tuber is not considered a favourite food among people; it's only preferred during times of food scarcity and for medicinal uses. Even so, the farmer removed it from their farmland since they thought it was a weed (Sonibare and Adeniran, 2014). With its attributes of being a highly invasive and overgrowing plant and being able to survive in harsh conditions (Celestine and David, 2015), it can be further studied for phytoremediation. Several reports from researchers have shown that some plants have the ability to remediate soil contaminated with petroleum oil (Aransiola *et al*., 2013; Gaji *et al*., 2018).

Effect of contaminated soil on sprouting and bulbil's emergence of *D. bulbifera* planted

The germination period of *D. bulbifera* was increased by the presence of contamination in the soil (SEO and IE), as shown in Figure 2. Plants in the control germinated after 28 days of planting, but the germination time at the other treatment levels was delayed by 29%–93% as the concentration of SEO increased. The *D. bulbifera* planted in IE soil germinated after 39 days, while those planted in 375 mL SEO soil germinated after 53 days of planting. This also reveals that soil contamination affects the sprouting time of *D. bulbifera* and bulbil emergence per day. It has also been observed with other crops grown on SEO or IE contaminated soil that their sprouting time, germination, and yield were delayed or ceased (Islam *et al*., 2015; Nwite and Alu, 2015; Adesina and Ashamo, 2019).

Also, there was a 23–43% delay in the emergence of D. bulbifera's bulbils as the concentration increased, while IE emerged (168 days) before 225 mL 15kg^{-1} emerged (172 days). Control had the first day of emergence (134 days), while 375 mL15kg^{-1} had the longest (191 days) (Figure 3).

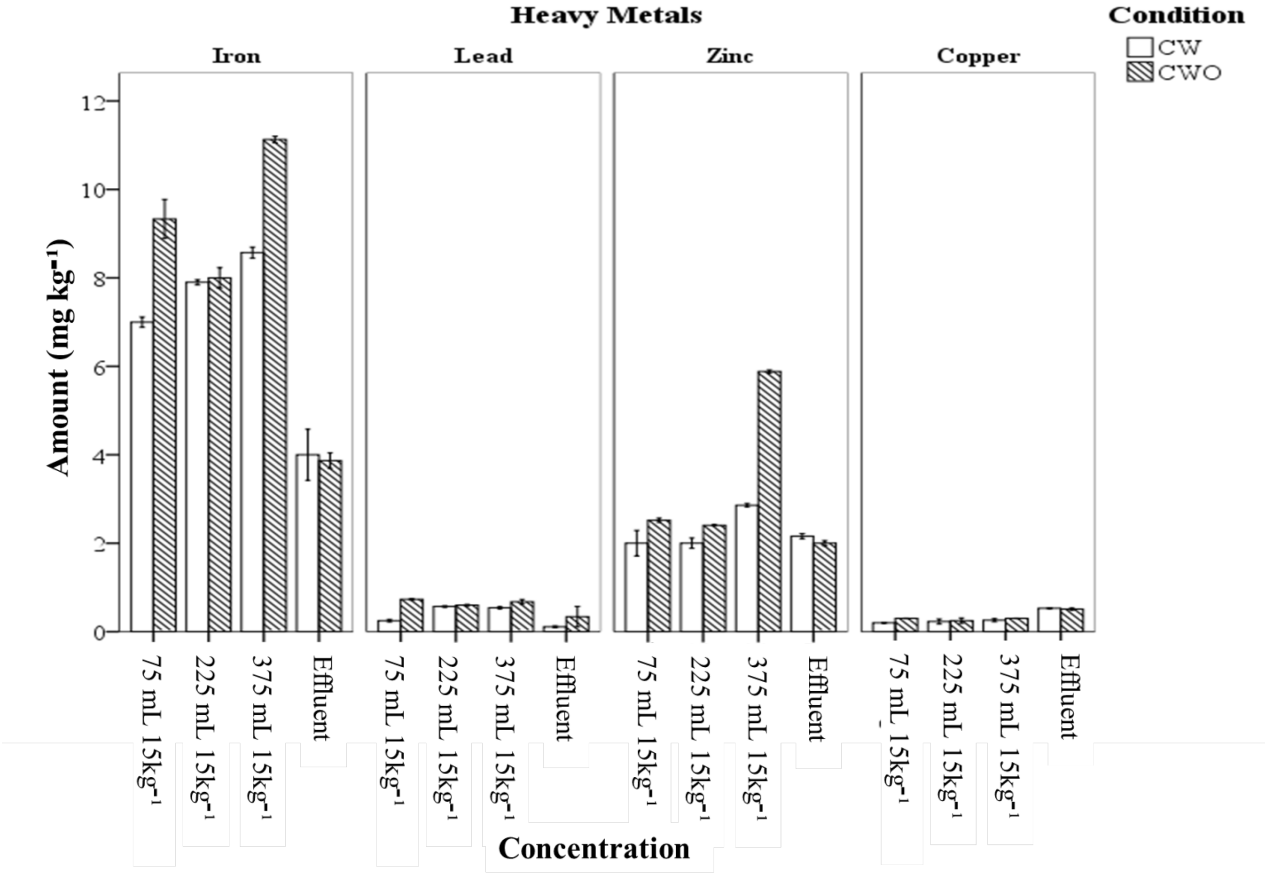

Figure 2: Heavy metals in contaminated soil with and without *D. bulbifera* plant
CW – Contaminated soil with *D. bulbifera* plant
CWO - Contaminated soil without *D. bulbifera* plant

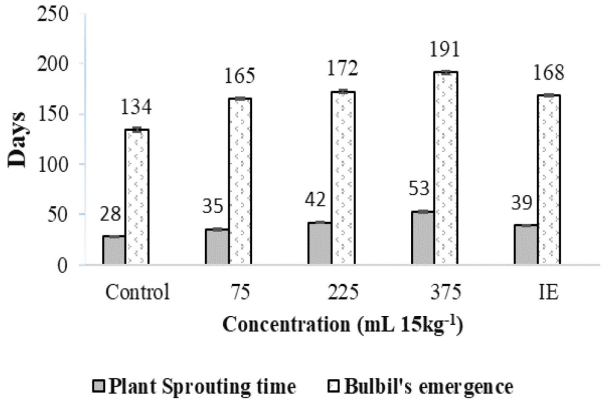

Figure 3: Sprouting and bulbil's emergence of D. bulbifera planted on at concentrated soil Please chanr ml to mL on x-axis

Effect of soil contamination on the leaf chlorophyll content of *D. bulbifera*

Figure 4 shows the relative value of the chlorophyll content of *D. bulbifera* planted on contaminated soil (SEO and IE) after 16 weeks. The least amount of chlorophyll content was observed in IE (274.06 mg g^{-1}) and the highest chlorophyll content in the control (3.49 mg g^{-1}). There was no significant difference ($p > 0.05$) between 75 mL 15kg^{-1} (3.34 mg g^{-1}) and 225 mL 15kg^{-1} (3.33 mg g^{-1}). Again, the chlorophyll content of *D. bulbifera*'s leaves grown on the contaminated soil was significantly reduced by 4.5%–21.6%. Smaller sizes and yellowing of the air potato's leaves were also observed in the contaminated soil, especially on 225 mL15kg^{-1} and 375 mL 15kg^{-1}. Similarly, Aniefiok *et al.* (2013) pointed out that the chlorophyll of *D. bulbifera's* leaves planted on a crude oil-polluted soil decreased with the

intensity of pollution. Likewise, Baruah *et al.* (2014) demonstrated that an increase in crude oil pollution on the soil decreased the chlorophyll content of a *Cyperus brevifolius* plant. The reduction in chlorophyll content was a result of heavy metal accumulation by the plant. In support of this, Shakya *et al*. (2008) revealed that Cu accumulation on the mosses and the leafy liverwort significantly inhibits their chlorophyll content.

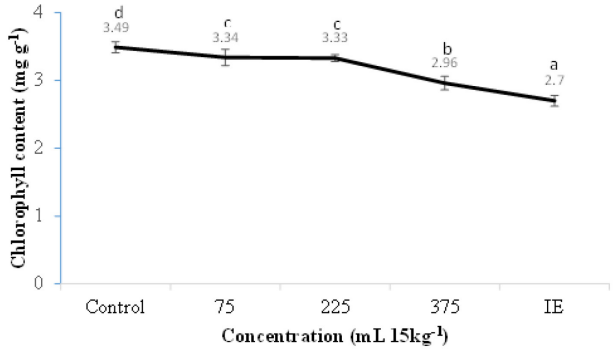

Figure 4: Chlorophyll content of D. bulbifera leaf after 16 weeks of planting Please chane ml to mL

According to Hussain *et al*. (2019), chlorophyll content and biomass are good bio-indicators of stress factors for plants in a polluted soil environment. The higher the chlorophyll content and the biomass, the greater the ability to cope with environmental stress. Both the fresh and dry weights of the harvested bulbils were reduced by soil contamination when compared to the control plant. The plant was stressed by SEO at a concentration of 375 mlper 15 kg and IE. The tolerance of *D. bulbifera* at this level was breached, as there was a significant reduction in chlorophyll content and bulbil biomass. Thus, the studied plant's ability to remediate at higher concentrations of pollution is also doubted.

Fresh and dry weight of harvested *D. bulbifera's* bulbils

The weight of bulbils produced by *D. bulbifera* decreased as the concentration of the contamination increased (Figure 5), except in the fresh weight of 375 mL kg^{-1} (47.03 g), which was greater than 225 mL $15kg^{-1}$ (43.0 g) after 16 weeks of planting. Control had the highest fresh weight (96.67 g), dry weight (56.67 g) and also was the largest in size (Figure 6), while bulbils from effluent had the least fresh and dry weight (20.21 g and 14.73 g, respectively). This outcome is consistent with the findings of Osuagwu *et al*. (2017), who found that the biomass of the plant they tested decreased as the soil's toxicity from spent engine oil rose.

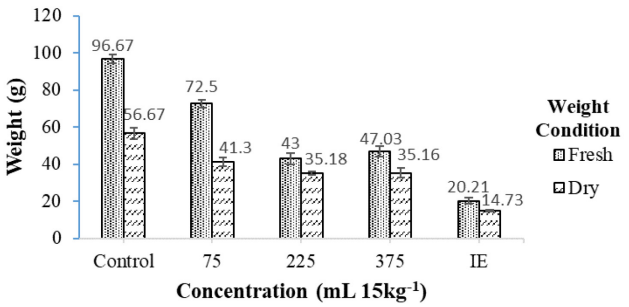

Figure 5: Fresh and dry weight of *D. bulbifera's* bulbils harvested

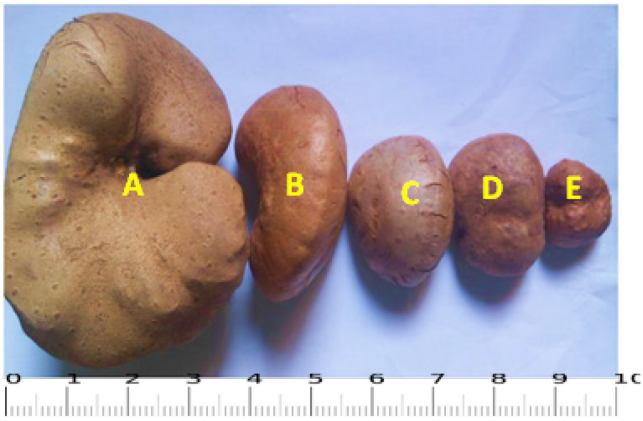

Figure 6: Harvested bulbils of *D. bulbifera* planted on soil contaminated with spent engine oil

Accumulation of heavy metals in the bulbils after 16 weeks of planting

The copper level of the control bulbils (0.01 mg kg^{-1}) was significantly different ($p < 0.05$) from others, as the IE had the highest quantity of copper (0.56 mg kg^{-1}). The control (1.26 mg kg^{-1}) was not significantly different ($p > 0.05$) from IE (1.52 mg kg^{-1}) in iron content, while 375 mL kg^{-1} (3.13 mg kg^{-1}) had the highest quantity of iron. The lead contents of 225 mL kg^{-1} (0.03 mg kg^{-1}) and 375 mL kg^{-1} (0.03 mg kg^{-1}) were not significantly different from each other but significantly different ($p < 0.05$) from other levels of treatment. The zinc present in the control bulbils was 0.41 mg kg^{-1}, and 225 mL$15kg^{-1}$ (0.82 mg kg^{-1}) was not significantly different ($p > 0.05$) from 75 mL$15kg^{-1}$ (0.72 mg kg^{-1}). Zinc content in 375 mL $15kg^{-1}$ (1.94 mg kg^{-1}) was significantly different ($p < 0.05$) from other treatments (Table 3). Also, the bioaccumulation of heavy metals on the plant's bulbils grown on the contaminated soil was shown in figure 7. Except for copper, all of the heavy metals under investigation had bioaccumulation factor values below 1. Copper's BAF is 1.05

in 75 mL15kg^{-1}, 1.75 in 225 mL15kg^{-1}, 1.63 in 375 mL15kg^{-1}, and 0.74 in IE.

This study shows that heavy metals (zinc, lead, iron, and copper) accumulate on the bulbils. Heavy metals have been

Table 3: Accumulation of heavy metals on the Bulbils after 16 weeks of planting

Concentration	Zinc(mg kg^{-1})	Lead(mg kg^{-1})	Iron(mg kg^{-1})	Copper(mg kg^{-1})
Control	0.41 ±0.01^{a}	0.00 ±0.00^{a}	1.26 ±0.03^{a}	0.01 ±0.00^{a}
75 mL15kg^{-1}	0.72 ±0.02^{b}	0.01 ±0.00^{a}	2.13 ±0.06^{b}	0.41 ±0.11^{b}
225 mL 15kg^{-1}	0.82 ±0.05^{b}	0.03 ±0.01^{b}	2.59 ±0.29^{c}	0.49 ±0.01^{b}
375 mL15kg^{-1}	1.94 ±0.11^{c}	0.03 ±0.01^{b}	3.13 ±0.01^{d}	0.49 ±0.02^{b}
IE	0.24 ±0.02^{a}	0.01 ±0.01^{a}	1.52 ±0.01^{a}	0.56 ±0.03^{b}

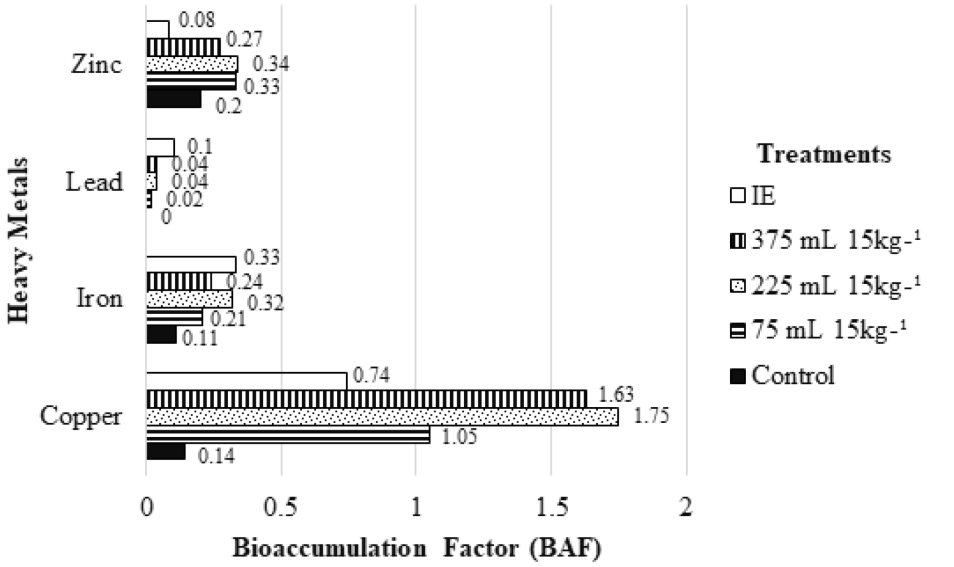

Figure 7: Bioaccumulation factor (BAF) of heavy metals in the plant bulbil



Figure 8: *D. bulbifera* (air potato) plant grown on the soil without contamination

reported in crops collected from markets, grown in agricultural fields, and polluted areas (Elbagermi *et al*., 2012; Abiya *et al*., 2018; Murtić *et al*., 2018; Mulat *et al*., 2019). The accumulation of lead (Pb) on the bulbils was relatively low when compared with other heavy metals. According to Rosen (2002), the fruit of a vegetable and an aerial fruit or crop do not readily accumulate lead, and air potatoes are also an aerial crop. It has been reported that heavy metals found in food crops, pose a potential hazard to humans through the dietary pathway (Batra, 2012). It is very risky to consume such food crops because their accumulation in the human body over a long period of time could cause great havoc. The heavy metals that were examined on the bulbil are in considerable amounts, not above the consumable limit set by WHO (2001) and FAO/WHO (2010) for food, except for iron, which is above permissible limits of 1.0 mg kg^{-1}. The biaccumulation factor (BAF) of copper in all the treatments is greater than 1, except in the IE. This indicates that *D. bulbifera* can easily absorb copper introduced to the soil by

SEO. The order of uptake of the heavy metals by the bulbils of the plant is Cu > Fe > Zn > Pb.

Conclusion

In this study, there is evidence that hydrocarbon oil and industrial effluent not only introduce heavy metals into the soil environment but also alter the soil's physicochemical properties and hinder the proper growth or survival of plants in it. However, considering the fact that the plant considered in this study was able to grow and produce bulbils at all concentrations of spent engine oil and industrial effluent pollution, it is an indication that it can tolerate those levels of pollution and should be investigated further for its bioremediation potential.

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