Remediation of Spent Engine Oil Polluted Soil Using Indigenous Plant Species

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ABSTRACT

Background and Objective: Soil contamination with engine oil and other petroleum hydrocarbons is a major problem in Nigeria. The study was carried out to assess the potential of *Chromolaena odorata*, *Aspilia africana* and *Axonopus compressus* in the remediation of used motor oil-contaminated soil. **Materials and Methods:** An equal volume of soil was spiked with 16% (w/w) of used motor oil and monitored for 90 days. The experiment was laid out in a complete randomized design in three replicates each. The test plants were harvested after 90 days and analyzed for the presence of heavy metals using AAS. The results obtained were analyzed using Microsoft Excel. **Results:** The variable concentrations of heavy metals and TPH were accumulated by the test plants from the contaminated soil and were stored in the root, shoot and leaf. Metal accumulation patterns were in the order: *Chromolaena odorat>A. africana>A. compressus*. *Chromolaena odorata* and *A. africana* exhibited characteristics typical of a phytoextractor while *A. compressus* could be applied as a phytostabiliser of spent engine oil-polluted soils. The result further showed that TPH content of *C. odorata* accumulated the highest level of TPH (178.43 mg/kg) in the leaf followed by *A. compressus* (46.58 mg/kg) and *A. africana* (26.26 mg/kg). **Conclusion:** Thus, *Chromolaena odorata*, *Aspilia africana* and *Axonopus compressus* possess hyper-accumulative uptake capacity for bioavailable residual oil heavy metals and therefore could be suitable for the phytoremediation of spent engine oil-contaminated soil.

INTRODUCTION

Remediation of contaminated soils falls into four major types viz: Chemical, physical, thermal, or biological techniques (phytoremediation and bioremediation)[1-3]. Most of the remediation techniques focus on exploiting or altering soil chemistry to either remove contaminants from the soil or to reduce their solubility and bioavailability[4-7]. Chemical remediation is based on chemical oxidation that eliminates harmful compounds from the contaminant. This technique is relatively fast but may negatively impact the surrounding ecosystem. Physical method (which includes excavation and washing) involves transportation of contaminated soil from source to an area for disposal, while in the second part (washing), contaminated soil is washed with organic solvents which eventually removes the contaminants[8].

Again, the high cost of chemicals and the threat to flora and fauna makes this method less applicable. Thermal technique entails desorption of and incineration which is very expensive with its attendant environmental pollution[9]. Based on this, a plant-based remediation technique known as phytoremediation is by far considered the most optimal remediation technique. It is a simple, vital, cost-effective, low-labor-intensive, widely acceptable, eco-friendly, sustainable, reliable and promising technology that is applicable in large areas, particularly when native, ecologically and socioeconomically valuable plants are used for the remediation[10].

The term phytoremediation consists of the Greek prefix "phyto" which means "plant" and the Latin suffix "Remedium" which means "renew, able to cure or restore"[11,12].

Plants remove contaminants from the soil through various techniques. These diverse ways in which plants interact with contaminants for eventual removal or degradation are referred to as phytoremediation techniques. Phytoremediation of contaminated soil can take place by phytoextraction, phytofilteration, phytostabilization, phytovolatilization, phytodegradation, rhizodegradation or phytodesalination[13,14]. This study was undertaken to evaluate remediation of spent engine oil polluted soil using indigenous plant species in Imo State Nigeria.

MATERIALS AND METHODS

Study area: Investigations were carried out from January to March, 2024 in the screen house of the Department of Biology, Federal University of Technology Owerri, Imo State located at Latitude 5.3866°N and Longitude 6.9916°E, respectively.

Pot experiment: Phytoremediation potentials of the selected hyperaccumulator species from the various auto mechanic workshops were evaluated *in vivo* by conducting pot experiments in the screen house. Three plant species (*Chromolaena odorata*, *Axpnopus compressus* and *Aspilia africana*) were selected based on phase one of this study as well as their dominance at mechanic workshops.

Experimental design: About 20 kg of soil was mixed with 16% spent engine oil, filled in polythene bags arranged in a complete randomized design and perforated at the base to avoid water logging. Each treatment was replicated three times. Two weeks after spiking with different concentrations of spent engine oil, about 100 g of soil samples were collected at the surface from each replicate, homogenized and sent to the laboratory for soil analysis prior to planting[15]. This was done to track the initial level of pollutants of concern in spent engine oil before transplanting[16].

Laboratory studies: After 12 weeks, a post-analysis of soil and plant tissues (root, shoot and leaf) was carried out to track the phytoremediation potentials of *Chromolaena odorata* and *Aspilia africana* at the various treatment levels.

Determination of heavy metals in plant parts (root, shoot and leaf): Each subsample was oven-dried at 70°C for 24 hrs. Acid digestion method of Sing and Jain[17] used for the digestion of grounded plant samples. One gram each of these was weighed into 50 mL capacity beaker, followed by addition of 10 mL mixture of analytical grade acids: HNO_3, H_2SO_4 and $HClO_4$ in a ratio 1:1:1. The beakers containing the samples were covered with watch glasses and left overnight. The digestion was carried out at a temperature of 70°C until about 4 mL was left in the beaker. Then, a further 10 mL of the mixture of acids was added. This mixture was allowed to evaporate to a volume of about 4 mL. After cooling, the solution was filtered to remove small quantities of waxy solids and made up to a final volume of 50 mL with distilled water. Quantitatively, the digested samples were transferred into a 125 mL plastic container, filtrated with 50 mL de-ionized water and metal analysis was performed with Buck scientific Atomic Absorption Spectrophotometer (Model GFA-EX7i, Shimadzu Corporation, Japan) using air acetylene flame with a digitalized read out system[17]. Results were expressed in mg/kg.

Determination of TPH in plant tissues (root, shoot and leaf): The plant parts from the different treatments were separately extracted in carbon tetrachloride. The extracts were then analyzed using IR spectroscopy following the method of Toth *et al.*[18].

Statistical analysis: Data collected was presented in charts and tables. Mean separation was done using Duncan Multiple Range Test at a 0.05% probability level. All statistical analysis was run using SAS package, version 20.

RESULTS

Metal accumulation in *C. odorata, A. africana* and *A. compressus* after 12 weeks of exposure to spent engine oil: Results of the analysis of selected heavy metals in below (soil) and above ground (root, leaf and shoot) of *C. odorata*, *A. compressus* and *A. africana* after 12 weeks of exposure to different concentrations of spent engine oil were presented in Fig. 1-11 while Fig. 12 shows the TPH accumulation in test plant tissues. As demonstrated in the figures, there was a marked variation in heavy metal accumulation patterns in the different plant tissues (root, leaf and shoot). Amount of Iron extracted by the plant tissues varied. Iron accumulation in the root was highest in *C. odorata* with a mean value of 27.39 mg/kg, followed by *A. africana* (27.21 mg/kg) while the lowest level accumulation of Fe was recorded in *A. compressus* with a mean value of 24.31 mg/kg. Some level of Fe was also observed in the leaf. *Chromolaena odorata* accumulated 236.91 mg/kg, while *A. africana* and *A. compressus* recorded 22.41 and 236.9 mg/kg, respectively. The highest phytoextraction rate was observed in *A. africana* and *C. odorata* while the least was recoreded in *A. compressus*. At the shoot tissue of the plants, Iron content fluctuated as follows: *Chromolaena odorata* (26.63 mg/kg), *A. africana* (24.92 mg/kg) and *A. compressus* (22.34 mg/kg), respectively (Fig. 1).

By the end of 12 weeks of the experiment, no amount of cobalt was detected in the soil samples. The root system accumulation cobalt by *C. odorata*, *A. africana* and *A. compressus* were 0.053, 0.0143 and 0.0141 mg/kg. The 0.082 mg/kg was recorded in the leaf of *C. odorata* with no values recorded for *A. africana* and *A. compressus* in the leaf (Fig. 2). However, it was observed that the highest level of cobalt (17.43 mg/kg) was found in the shoot of *C. odorata* followed by *A. compressus* with mean value of 0.142 mg/kg and *A. africana* (0.053 mg/kg), respectively.
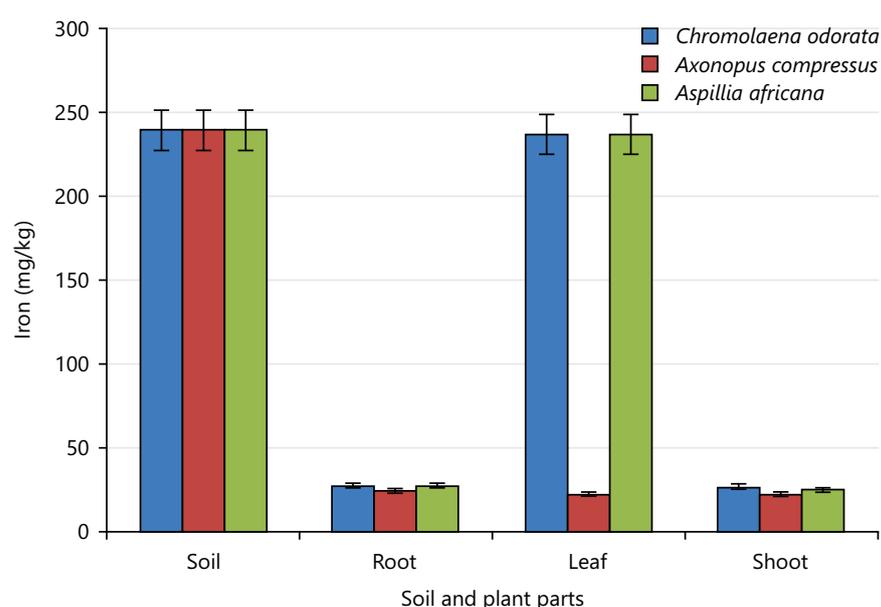
Fig. 1: Concentration of iron in soil, root, leaf and shoot of *C. odorata*, *A. compressus* and *A. africana* after 12 weeks of exposure to spent engine oil
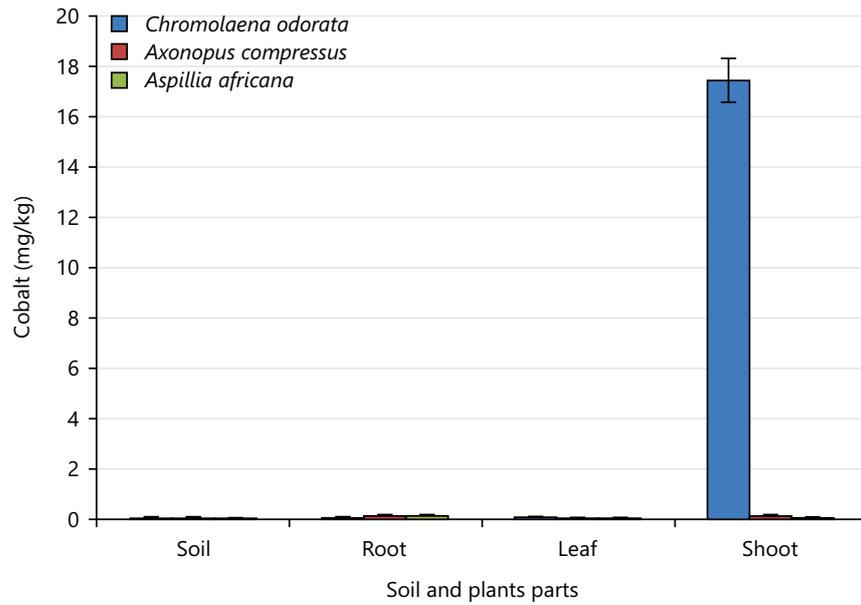
Fig. 2: Concentration of cobalt in soil, root, leaf and shoot of *C. odorata*, *A. compressus* and *A. africana*
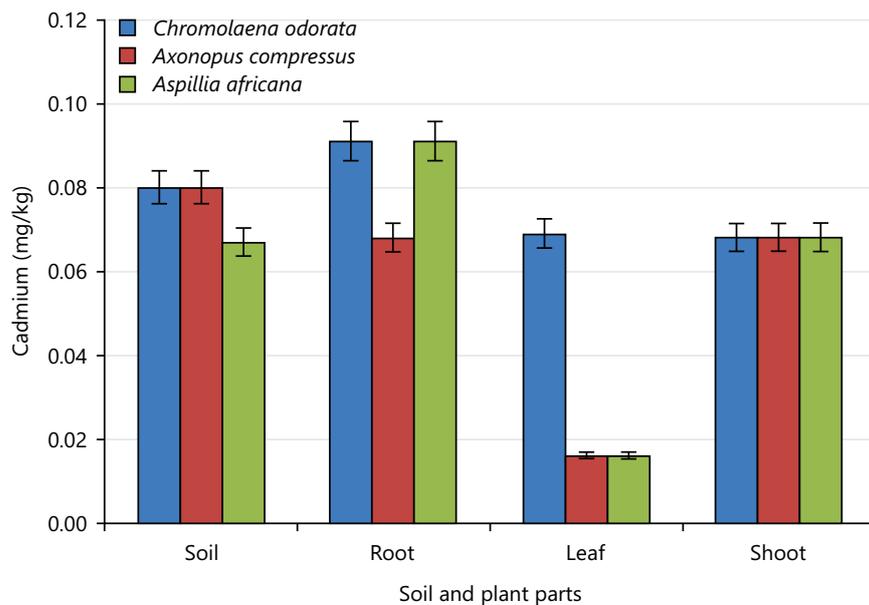
Fig. 3: Concentration of cadmium in soil, root, leaf and shoot of *C. ordonata*, *A. compressus* and *A. africana*

Cadmium accumulation was recorded mostly in the root of *C. odorata* and *A. africana* (0.091 mg/kg) while the least accumulation in root was recorded in *A. compressus* (0.068 mg/kg). Equal level of cadmium was observed in the shoot for each plant (0.078 mg/kg) as shown in Fig. 3. The highest accumulation of Arsenic was observed in the shoot by *C. odorata* (12.44 mg/kg) while the least level (0.127 mg/kg) was recorded in the leaf. A similar value (0.127 mg/kg) was also recorded for *A. africana* in the leaf (Fig. 4).

Uptake of manganese by *C. odorata* was more pronounced in the shoot when compared with other test plant parts. Equal mean values of 0.543 mg/kg were recorded in the roots of the three plants under study. However, the leaf recorded equal mean values of 0.668 mg/kg for *C. odorata* and *A. africana* (Fig. 5).
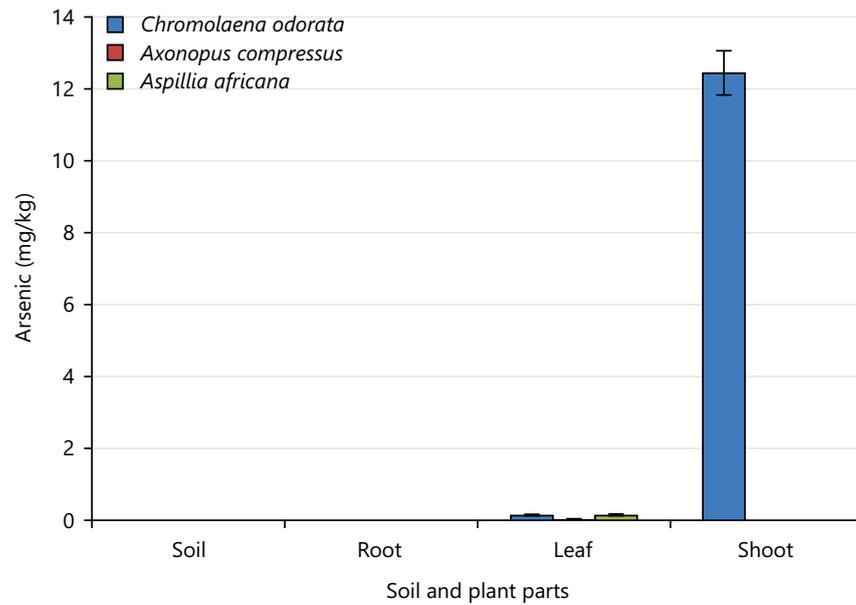
Fig. 4: Concentration of arsenic in soil, root, leaf and shoot of *C. odorata*, *A. compressus* and *A. africana*
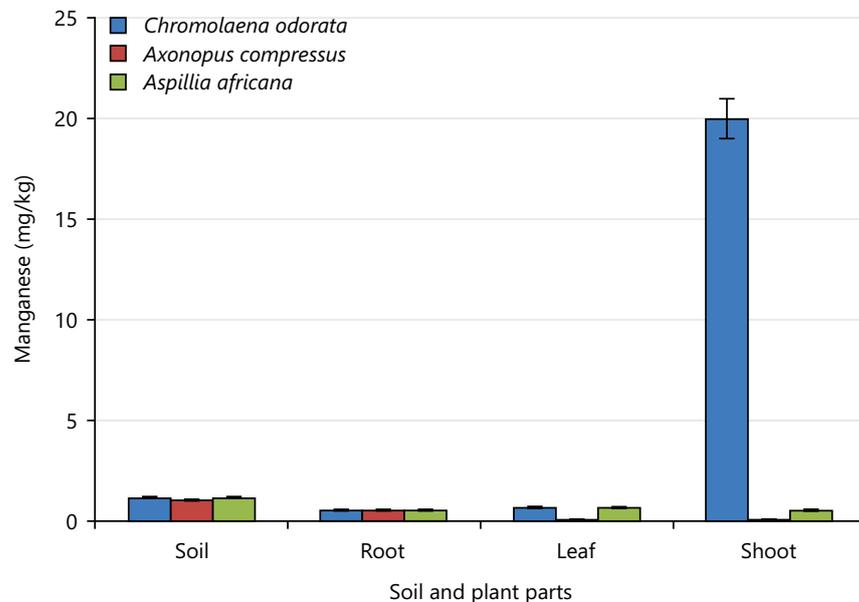
Fig. 5: Concentration of manganese in soil, root, leaf and shoot of *C. ordonata*, *A. compressus* and *A. africana*

The mean lead concentration values in root were: *Chromolaena odorata* (0.063 mg/kg), *A. compressus* (0.064 mg/kg) and *A. africana* (0.048 mg/kg). Increased level of accumulation in the aerial part of the plants was also observed with respect to lead (Fig. 6). The leaves of *C. odorata*, *A. compressus* and *A. africana* had 0.348, 0.094 and 0.348 mg/kg, respectively. With respect to the shoot accumulation of Lead, *C. odorata* recorded the highest accumulation with mean value of 0.348 mg/kg followed by *A. compressus* (0.064 mg/kg) and *A. africana* (0.053 mg/kg).

Ability of the plant species to phytoextract zinc from the soil also varied. Mean zinc content in roots for *C. odorata*, *A. compressus* and *A. africana* were 1.038, 4.69 and 4.266 mg/kg; the leaf content was 2.203, 4.495 and 3.761 mg/kg. The shoot accumulations were 4.49, 12.66 and 11.481 mg/kg (Fig. 7). Concentration of nickel in root, leaf and shoot tissues varied as follows: *Chromolaena odorata* (3.55 mg/kg), *A. compressus* (27.34 mg/kg) and 2.761, 28.23, 27.34 and 22.17 mg/kg; while 28.23 mg/kg was observed in the shoot for *C. odorata* with nil recorded in *A. compressus* and *A. africana* (Fig. 8).
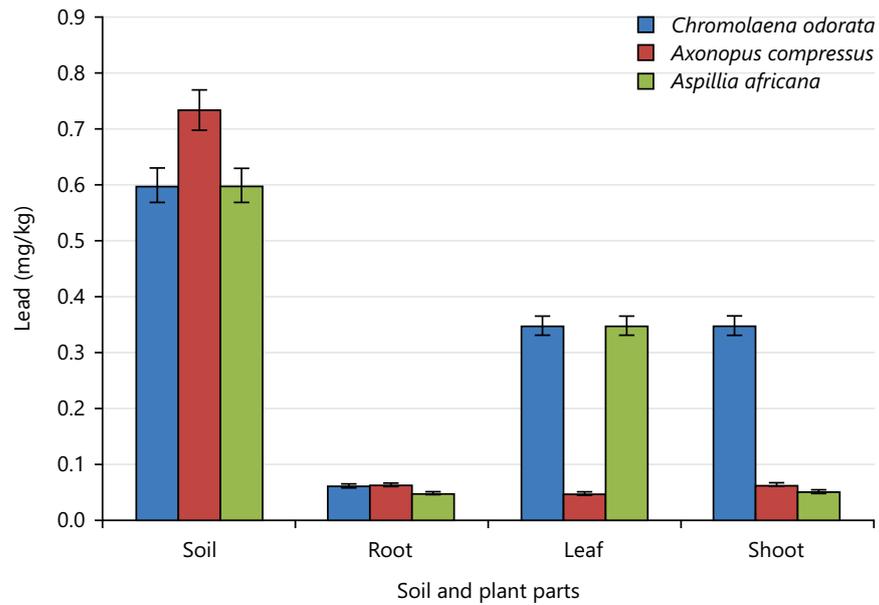
Fig. 6: Concentration of lead in soil, root, leaf and shoot of *C. odorata*, *A. compressus* and *A. africana*
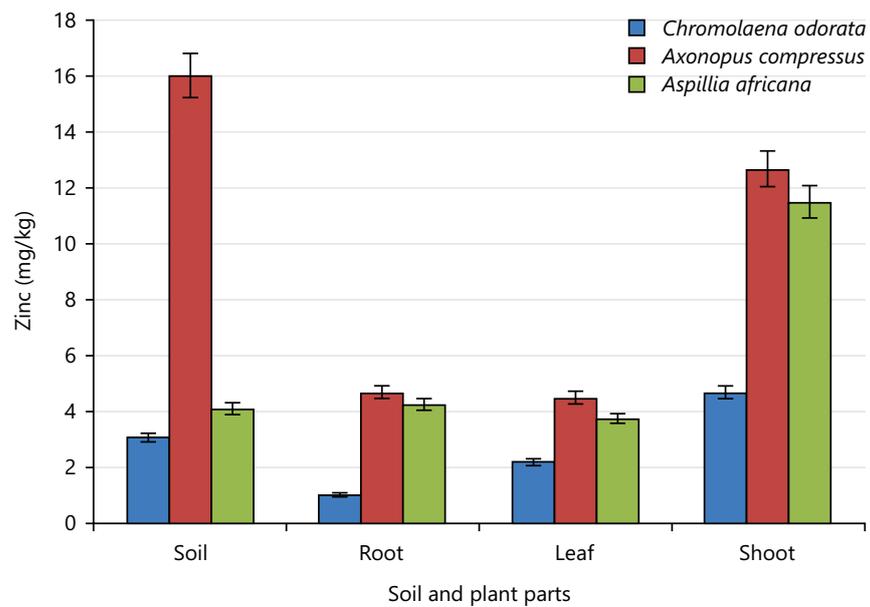
Fig. 7: Concentration of zinc in soil, root, leaf and shoot of *C. odorata*, *A. compressus* and *A. africana*

The highest level of copper in soil treated with *C. odorata* was high when compared with other test plants. In the root, concentration of copper in *C. odorata*, *A. compressus* and *A. africana* are 5.72, 0.068 and 0.04 mg/kg (Fig. 9). Mean concentration of copper also varied in the leaf and shoot as follows: 22.63, 0.068, 22.63, 0.04 and 0.599 mg/kg. The least accumulation of copper was recorded in *A. compressus* (0.04 mg/kg).

The uptake of chromium by the test plants indicated that *C. odorata* accumulated the highest level of chromium in root, leaf and shoot while the least accumulation was observed in *A. compressus*. In the root, the mean values of chromium recorded were *C. odorata* (8.21mg/kg), *A. compressus* (0.599 mg/kg) and *A. Africana* (0.599 mg/kg). In the leaf tissue, mean concentration were *C. odorata* (22.3 mg/kg) and 0.14 mg/kg for *A. compressus* and *A. africana*, respectively. Mean accumulation by *C. odorata*, *A. compressus* and *A. africana* in the shoot was 22.30, 0.588 and 0.589 mg/kg (Fig. 10).
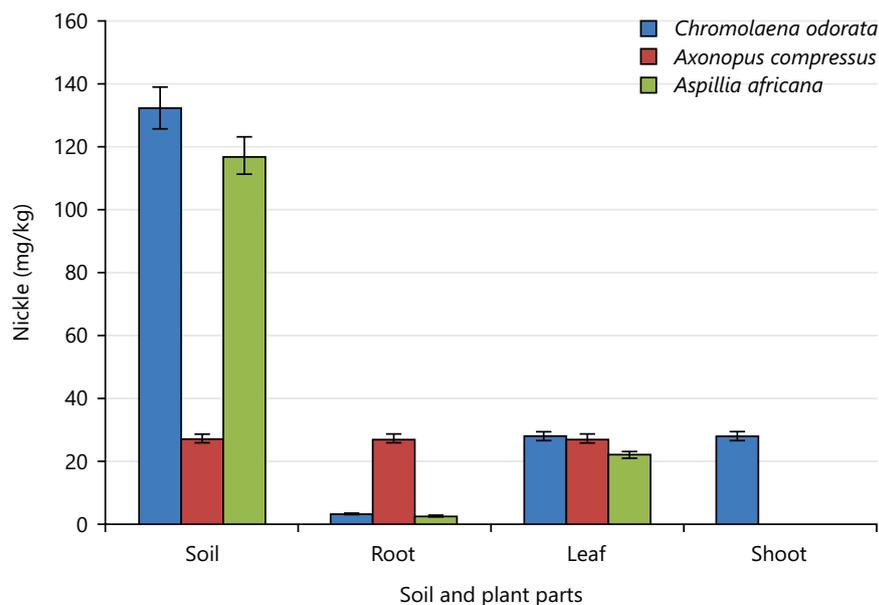
Fig. 8: Concentration of nickel in soil, root, leaf and shoot of *C. odorata*, *A. compressus* and *A. africana*
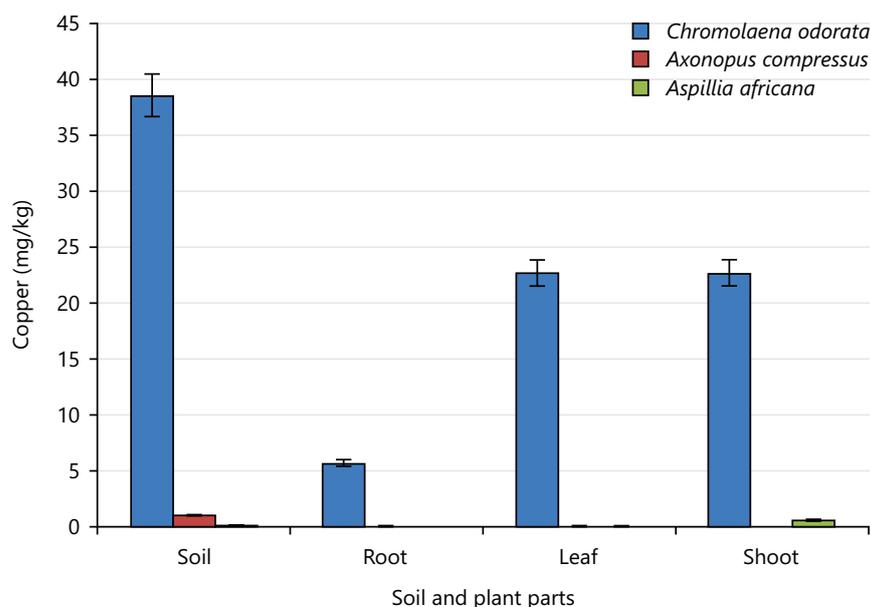
Fig. 9: Concentration of copper in soil, root, leaf and shoot of *C. odorata*, *A. compressus* and *A. africana*

TPH accumulation in test plant tissues: The TPH concentration in the shoot revealed that the mean accumulation in *C. odorata*, A. *compressus* and *A. africana* was 13.77, 10.34 and 0.068 mg/kg. The result further showed that TPH content in the leaf of *C. odorata* accumulated the highest level of TPH (178.43 mg/kg) in the leaf followed by *A. compressus* (46.58 mg/kg) and *A. africana* (26.26 mg/kg). The presence of high levels of TPH in plant tissues indicates that the active uptake of hydrocarbons from the soil was taking place (Fig. 11).

Correlation between TPH concentration in soil and plant tissues: In order to understand the relationship between the concentration of TPH in soil and plant tissues, correlation analysis was performed as shown in Fig. 12. Results obtained revealed that there was a significant and positive relationship ($r = 0.74$, $p = 0.004$) at 0.05 probability level between spent TPH content in the soil and root. This might
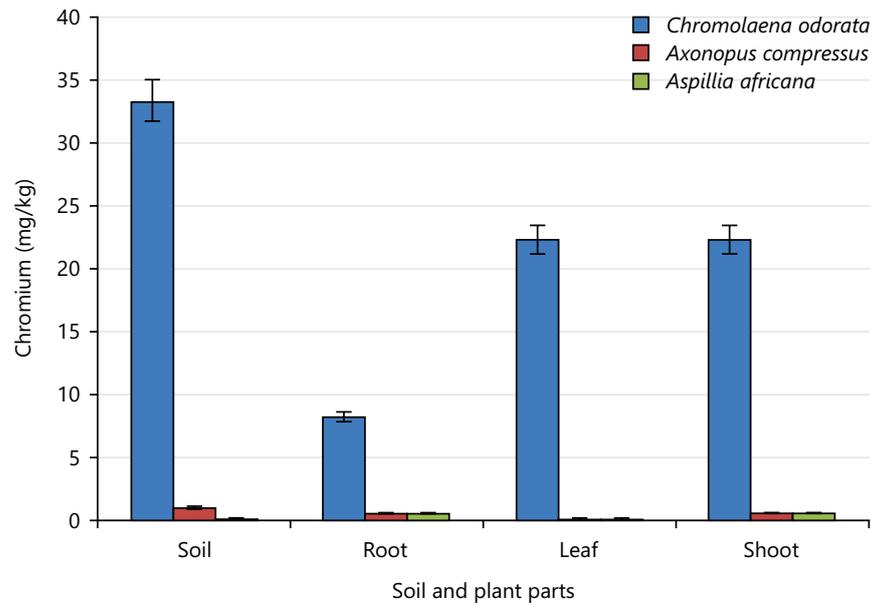
Fig. 10: Concentration of chromium in soil, root, leaf and shoot of *C. odorata*, *A. compressus* and *A. africana*
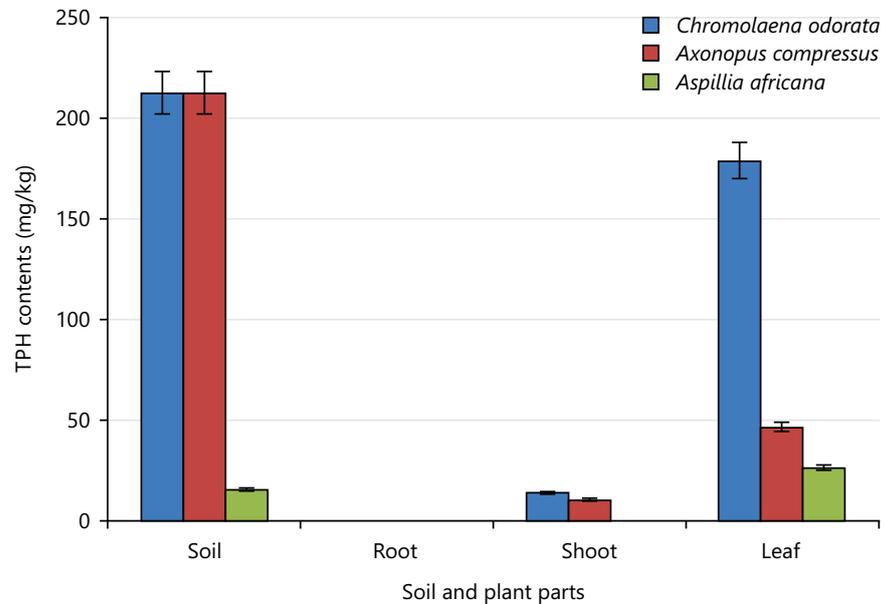
Fig. 11: TPH contents in soil, root, leaf and shoot of *C. ordonata*, *A. compressus* and *A. Africana*

be a result of an increase in concentration of TPH in the soil, which also increases the accumulation of TPH by the plant species thus:

$$Y = 378.26 + 1.8914X$$

where, Y is the concentration of TPH in plant roots and X is the concentration of TPH in soil. This means that TPH level in soil positively correlates with TPH in plant roots. In other words, an increase in TPH level in soil increases TPH content in roots and vice versa.

DISCUSSION

The study has established the accumulation of heavy metals in the roots, shoots and leaves of indigenous plants. As shown in the figures, there was a marked variation in heavy metal accumulation patterns in the different plant tissues (root, leaf and shoot). An increase in TPH level in soil increases TPH content in roots and vice versa.
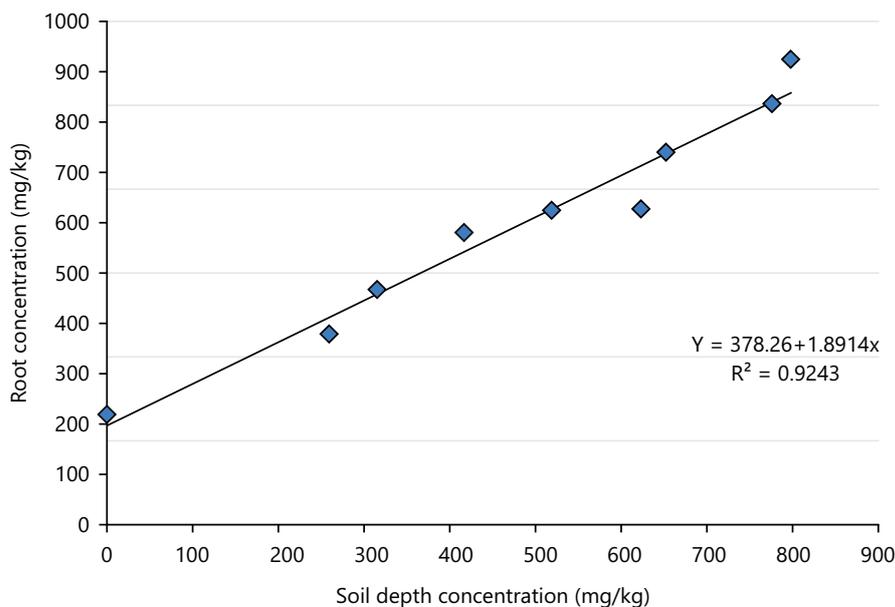
Fig. 12: Linear regression between TPH concentration in contaminated soil and root

This may be an indication that the test plants (*C. odorata*, *A. africana* and *A. compressus*) possess the potential to remediate sites with low to medium contamination[19]. This was evidenced by the survival and continued, though concentration-dependent reduction in the growth of the test plants, in spent engine oil contaminated soils[20,21]. The ability of *C. odorata*, *A. africana* and *A. compressus* to grow in soils contaminated with spent engine oil suggests that the species may have the ability to phytodegrade the toxicants resident in spent engine oil (Fig. 1-11). This result was similar to the findings of Ekanem *et al.*[22].

Similar growth responses have been reported for seedlings of *Terminalia ivorensis*, *Terminalia superba* and *Khaya senegalensis*[23]. A significant and positive correlation was recorded between TPH concentration in soil and plant tissue. This result was in agreement with the report of Ogeleka *et al.*[12]. The reason might be that an increase in TPH content in soil resulted to increased level of TPH in plants[18].

CONCLUSION

The ability of *O. odorata*, *A. africana* and *A. compressus* to bioaccumulate and transfer heavy metals in their aboveground tissues (root, shoot and leaf) suggested that these plants could be used to remediate spent engine oil contaminated sites. Thus, the three plant species have demonstrated the ability to tolerate heavy metal stress, grow and accumulate biomass in spent engine oil polluted soil. This underscore the need to further explore the adaptability of these indigenous plant species to heavy metals for their selective exploitation in phytoremediation of spent engine oil polluted sites.

SIGNIFICANCE STATEMENT

The ability of three indigenous plant species to remediate spent engine oil-polluted soil was carried out in this study. This was done to apply eco-friendly and cost-effective methods of remediation of polluted sites. This study will enhance our knowledge of the remedial efficacy of indigenous plant species instead of using chemical methods which are costly and environmentally unsafe in the tropics.

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