Faculty of Natural and Applied Sciences Journal of Scientific Innovations
Print ISSN: 2814-0877 e-ISSN: 2814-0923
www.fnasjournals.com
Volume 5; Issue 2; December 2023; Page No. 17-29.

PHYTOACCUMULATION POTENTIALS OF THREE INDIGENOUS PLANT SPECIES GROWN IN USED ENGINE OIL-POLLUTED SOIL

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Abstract

The study was carried out to investigate the potentials of *Chromolaena odorata*, *Aspillia africana*, and *Axonopus compressus* in the remediation of used motor oil contaminated soil. An equal volume of soil was spiked with 20% (w/w) of used motor oil and monitored for 90 days. The test plants were harvested after 90 days and analyzed for the presence of heavy metals using AAS. Results obtained revealedthat 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: *C. odorat>A. africana>A. compressus*. *C. 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). Thus, *Chromolaena odorata*, *Aspillia africana, and Axonopus compressus* possess hyper-accumulative uptake capacity for bioavailable residual heavy metals and TPH therefore could be suitable for and applied in the phytoremediation of spent engine oil contaminated Agricultural soils in the tropics.

Keywords: Phytoaccumulation, *Chromolaena Odorata*, *Aspillia Africana*, *Axonopus compressus*

Introduction

In Nigeria, automobile workshops are usually sited in government-allocated areas known as mechanic villages. Activities carried out in these designated areas include but are not limited to panel beating, vulcanizing, charging of car batteries, spray painting, repairs and servicing of motor vehicles (Udebuani et al., 2016). Soil contamination resulting from indiscriminate spills of petroleum and its allied products is considered a serious challenge in most developing countries. Spent engine oil is viewed as oil that has been used and as a result contaminated by chemical impurities which contributes to environmental degradation (Ekperusi & Aigbodion, 2014; Onwuka et al., 2012). It is usually obtained after servicing and subsequent draining from automobile and generator engines (Sharifi, et al., 2007). As a result of its chemical composition, world-wide dispersion and effects on the environment, spent engine oil is considered a serious environmental challenge which contributes to mutagenicity and carcinogenicity with global ramifications.

Soils are a rich ecological system comprising of both abiotic and biotic matter with varying levels of interaction (Yahaya et al., 2021) and provision of ecosystem services. Globally, human societies are interconnected economies that rely on services provided by the ecosystems which constitute the foundation upon which human existence is based. The resilience of socio-ecological systems solely depends on the sustainable management of these ecosystems, hence, the need for a sustainable eco-friendly management strategy to curb the menace of environmental contamination (Osubor & Anoliefo, 2004; Odjegba & Sadiq, 2002; Ameh et al.,,2011). Remediation of contaminated soils falls into four major types viz: chemical, physical, thermal or biological techniques (phytoremediation and bioremediation). Most of the remediation techniques focus on exploiting or altering soil chemistry to either remove contaminants from the soil or reduce their solubility and bioavailability (Jidere & Akamigbo, 2009). 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. The physical method (which includes excavation and washing) involves the transportation of contaminated soil from the source to an area for disposal, while in the second part (washing), contaminated soil is washed with organic solvents which eventually removes the contaminants (Anukwa et al.,2021). Again, the high cost of chemicals and the threat to flora and fauna makes this method less applicable. Thermal technique entails desorption and incineration which is very expensive with its attendant environmental pollution (Singh & Jain, 2003).

Given this, 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 which is applicable in large areas, particularly when native, ecologically and socioeconomically valuable plants are used for the remediation (Alford et al., 2010). Phytoremediation, also known as green-remediation is defined as the clean-up of contaminated sites using a unique diversity of plants. This is a remediation technique that uses plants to detoxify contaminated soils. It presents an efficient, "green clean," environmental, low-cost, and eco-friendly technology that uses plants to reduce or remove inorganic and organic pollutants from the environment (Pilon-Smits, 2005). This study aims to evaluate the phytoaccumulation potentials of three indigenous plant species for possible reclamation of spent engine oil-contaminated agricultural soils.

Materials and Methods

Investigations were carried out 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. 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 *Aspillia africana*) were selected based on phase one of this study as well as their dominance at mechanic workshops. Soil samples with no history of oil pollution were collected from a depth of 0-20cm within the Federal University of Technology Owerri using an auger of approximately 7.5cm diameter and taken to the laboratory for pre-planting soil analysis. The soil samples were air-dried and pre-sieved with <2mm sieve and used for physicochemical determination. Vegetative parts of the plant species (stem cuttings of *Chromolaena odorata*, *Axonopus compressus* and *Aspillia africana*) were collected from an area with no trace of spent oil pollution and stabilized in the nursery for two (2) weeks by which time an average of four (4) fully expanded leaves per plant had been developed before been used for the study.

An equal volume of pre-sieved soil (20kg) was filled in Polythene bags and arranged at 0.5m spacing between polybags and 1m between replications and perforated at the base to avoid water logging. Concentrations of spent engine oil spiked included 20% (w/w) which was allowed to stabilize for two (2) weeks to simulate the condition of the natural spill (Plate 1). Thereafter, 100g of soil samples were collected at the surface and sent to the laboratory for soil analysis (Tóth, & Montanarela, 2013). This was done to track the initial level of pollutants of concern in spent engine oil before transplanting (Njoku et al., 2009).

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Plate 1: Experimental set-up for phytoremediation studies

Two weeks after the nursery establishment of the seedlings, plants with three to four fully expanded leaves were selected for transplanting into the polythene bags containing the respective treatments/control; one plant per pot. Each of the polythene bags was watered with 200 mls of water a day before transplanting. Overall, three plant species (*Chromolaena odorata*, *Axonopus compressus* and *Aspillia africana*) were tested in one treatment soil each having three replicates.

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 *Aspillia africana* at the various treatment levels. The acid digestion method of Youssef and Tayel (2004) was used for the digestion of grounded plant samples. 1 g each of these was weighed into a 50mL 50-capacity beaker, followed by the addition of a 10 mL mixture of analytical grade acids: HNO3; 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 4mL was left in the beaker. Then, a further 10mL of the mixture of acids was added. This mixture was allowed to evaporate to a volume of about 4mL. 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 125ml plastic container, filtrated with 50ml de-ionized water and metal analysis was performed with Buck scientific Atomic Absorption Spectrophotometer (Model GFA-EX7i, Shimadzu Corporation, Japan) using an air acetylene flame with a digitalized readout system (Sabate et al., 2006). Results were expressed in mg/kg.

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 Raymond and Harrison, (2018). Data collected was presented in charts and tables. Mean separation was done using the Duncan Multiple Range Test at a 0.05% probability level. All statistical analysis was run using the SAS package, 20 version.

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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 is presented in Figures 1 to 11 while Figure 12 shows the TPH accumulation in test plant tissues. As demonstrated in the figures, there was marked variation in heavy metal accumulation patterns in the different plant tissues (root, leaf and shoot). The amount of Iron extracted by the plant tissues varied. Iron accumulation in the root was highest in *C. odorata* with a mean value of 27.39mg/kg, followed by *A. africana* (27.21mg/kg) while the lowest level accumulation of Fe was recorded in *A. compressus* with a mean value of 24.31mg/kg. Some level of Fe was also observed in the leaf. *C. odorata* accumulated 236.91mg/kg, while *A. africana* and *A. compressus* recorded 22.41mg/kg and 236.9mg/kg respectively. The highest phytoextraction rate was observed in *A. africana* and *C. odoara* while the least was recorded in *A. compressus*. At the shoot tissue of the plants, Iron content fluctuated as follows: *C. odorata* (26.63mg/kg), *A. africana* (24.92mg/kg) and *A. compressus* (22.34mg/kg) respectively(Figure 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 0.053mg/kg, 0.0143mg/kg and 0.0141mg/kg. 0.082mg/kg was recorded in the leaf of *C. odorata* with no values recorded for *A. africana* and *A. compressus* in the leaf(Figure 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 a mean value of 0.142mg/kg and *A. africana* (0.053mg/kg) respectively. Cadmium accumulation was recorded mostly in the root of *C. odorata* and *A. africana* (0.091mg/kg) while the least accumulation in root was recorded in *A. compressus* (0.068mg/kg). Equal level of Cadmium was observed in the shoot for each plant (0.078 mg/kg) as shown in Figure 3. The highest accumulation of Arsenic was observed in the shoot by *C. odorata* (12.44 mg/kg) while the lowest level (0.127 mg/kg) was recorded in the leaf. A similar value (0.127mg/kg) was also recorded for *A. africana* in the leaf (Figure 4). Uptake of Manganese by *C. odorata* was more pronounced in the shoot when compared with other test plant parts. Equal mean values of 0.543mg/kg were recorded in the roots of the three plants under study. However, the leaf recorded equal mean values of 0.668mg/kg for *C. odorata* and *A. africana* (Figure 5).

The mean Lead concentration values in root were: *C. odorata* (0.063mg/kg); *A. compressus* (0.064mg/kg)and *A. africana* (0.048mg/kg). An increased level of accumulation in the aerial part of the plants was also observed concerning Lead (Figure 6). The leaf of *C. odorata, A. compressus* and *A. africana* had 0.348mg/kg, 0.094mg/kg and 0.348mg/kg respectively. Concerning the shoot accumulation of Lead, *C. odorata* recorded the highest accumulation with a mean value of 0.348mg/kg followed by *A. compressus* (0.064mg/kg) and *A. africana* (0.053mg/kg). The 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 1.038mg/kg, 4.69mg/kg and 4.266mg/kg; the leaf content was 2.203mg/kg, 4.495mg/kg and 3.761mg/kg. The shoot accumulations were 4.49mg/kg, 12.66mg/kg and 11.481mg/kg(Figure 4.14). Concentration of Nickel in root, leaf and shoot tissues varied as follows: *C. odorata* (3.55mg/kg), *A. compressus* (27.34mg/kg) and 2.761mg/kg; 28.23mg/kg, 27.34mg/kg and 22.17mg/kg; while 28.23mg/kg was observed in the shoot for *C. odorata* with nil recorded in *A. compressus* and *A. africana*(Figure 7)
The highest level of Copper in soil treated with *C. odorata* was high when compared with other test plants. In the root, the concentrations of Copper in *C. odorata, A. compressus* and *A. africana* were 5.72mg/kg, 0.068mg/kg, and 0.04mg/kg(Figure 8). The mean concentration of Copper also varied in the leaf and shoot as follows: 22.63mg/kg, 0.068mg/kg 22.63mg/kg, 0.04mg/kg and 0.599mg/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 the 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* (0.599mg/kg) and *A. Africana* (0.599mg/kg). In the leaf tissue, the mean concentration were *C. odorata* (22.3mg/kg), and 0.14mg/kg for *A. compressus* and *A.*

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africana respectively. Mean accumulation by *C. odorata*, *A. compressus* and *A. africana* in the shoot were 22.30mg/kg, 0.588mg/kg and 0.589mg/kg(Figure 9).

TPH accumulation in test plant tissues

TPH concentrations in the shoot revealed that the mean accumulation in *C. odorata*, *A. compressus* and *A. africana* were 13.77mg/kg, 10.34mg/kg and 0.068mg/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 (Figure 12).

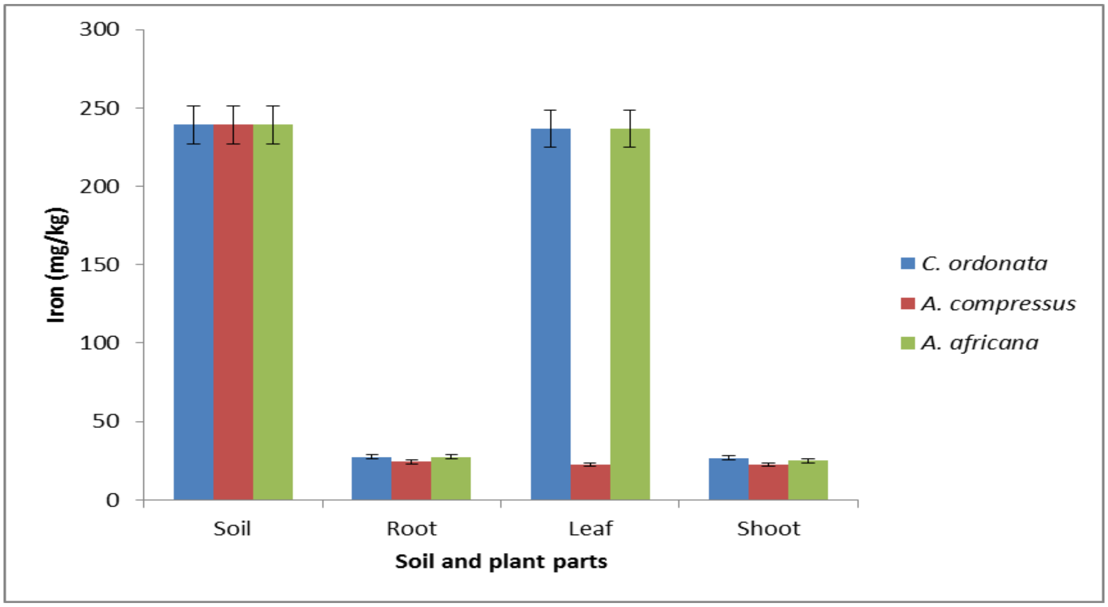

Figure 1: Concentration of iron in the soil, root, leaf and shoot *of C. odorata, A. compressus* and *A.africana* after 12 weeks of exposure to spent engine oil.

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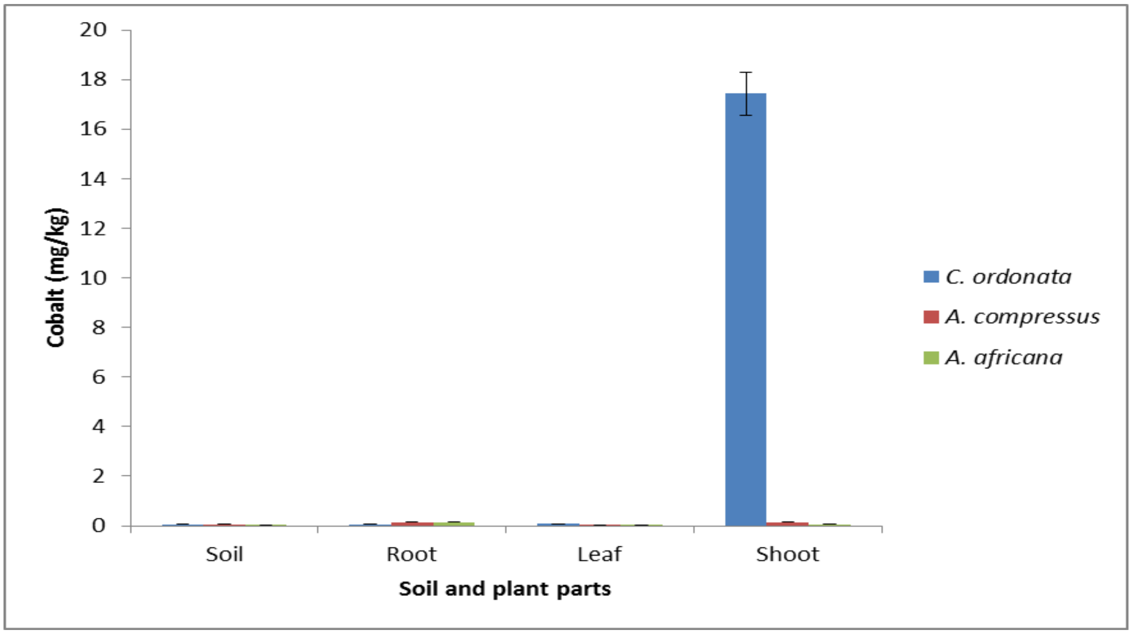

Figure 2: Concentration of cobalt in soil, root, leaf and shoot of *C. odorata*, *A. compressus* and *A. africana*

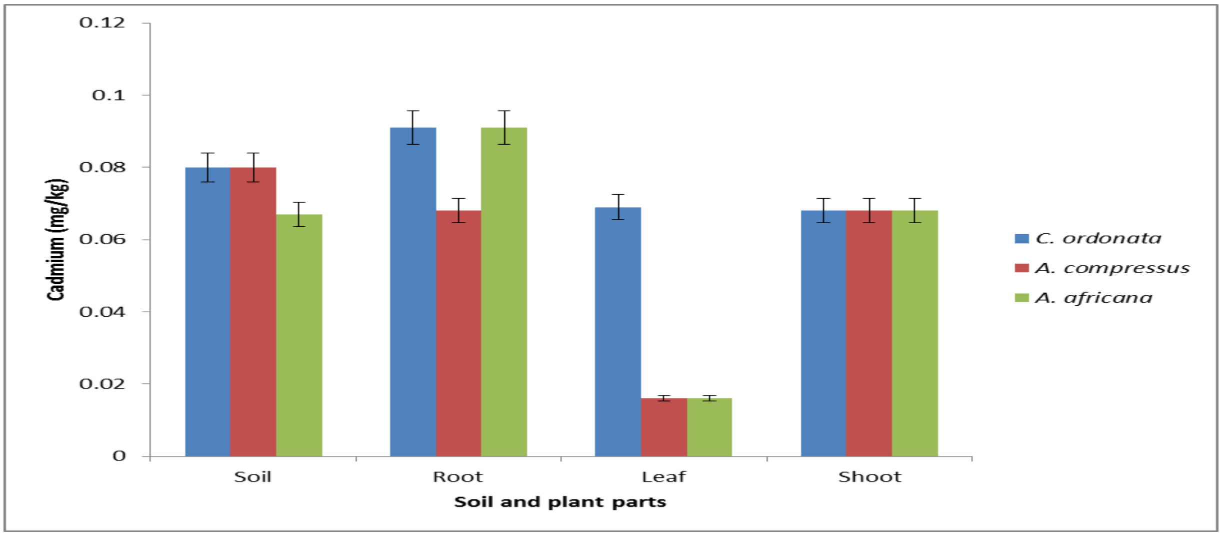

Figure 3: Concentration of cadmium in soil, root, leaf and shoot of *C. ordonata*, *A. compressus* and *A. africana*

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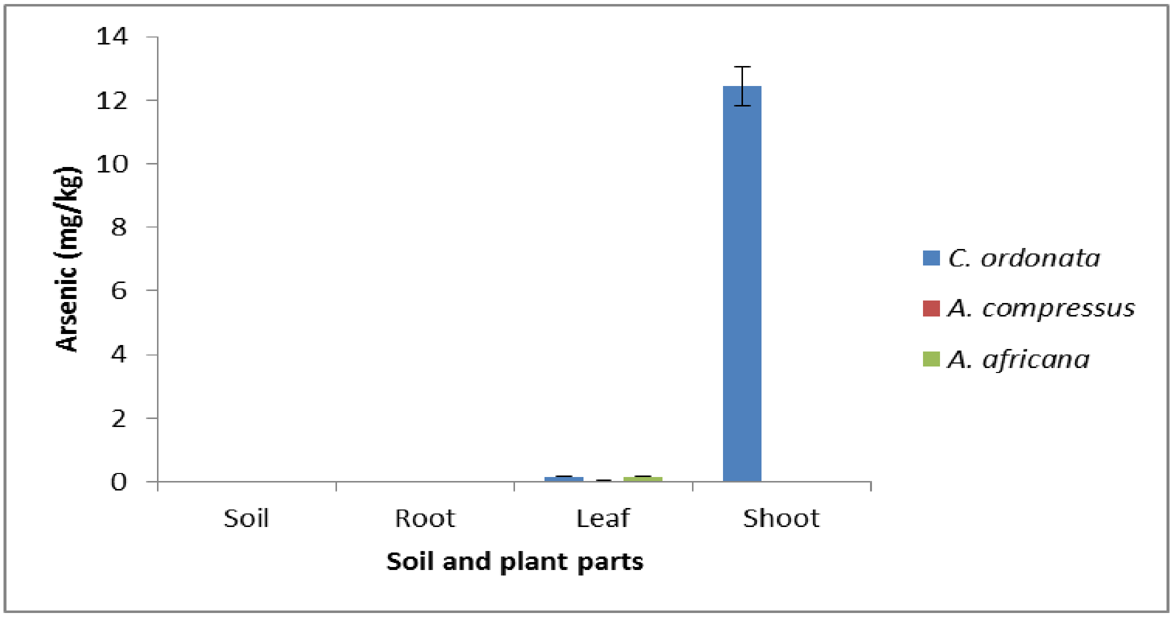

Figure 4: Concentration of arsenic in soil, root, leaf and shoot of *C. odorata, A. compressus*and *A. africana*

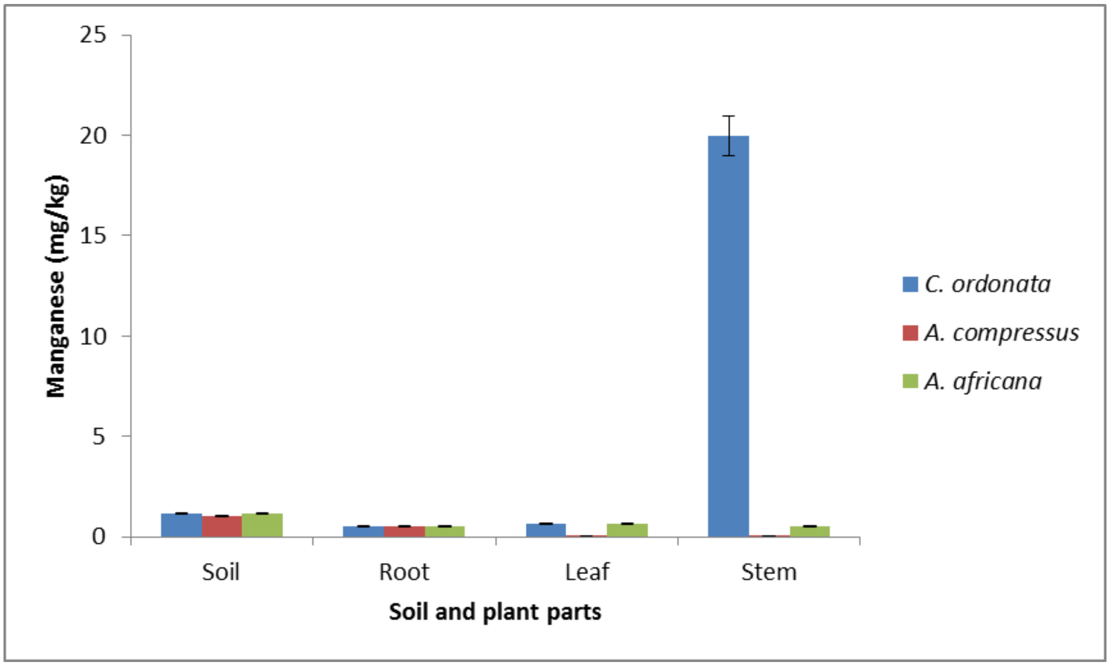

Figure 5: Concentration of manganese in soil, root, leaf and shoot of *C. ordonata, A.compressus*and *A. africana*

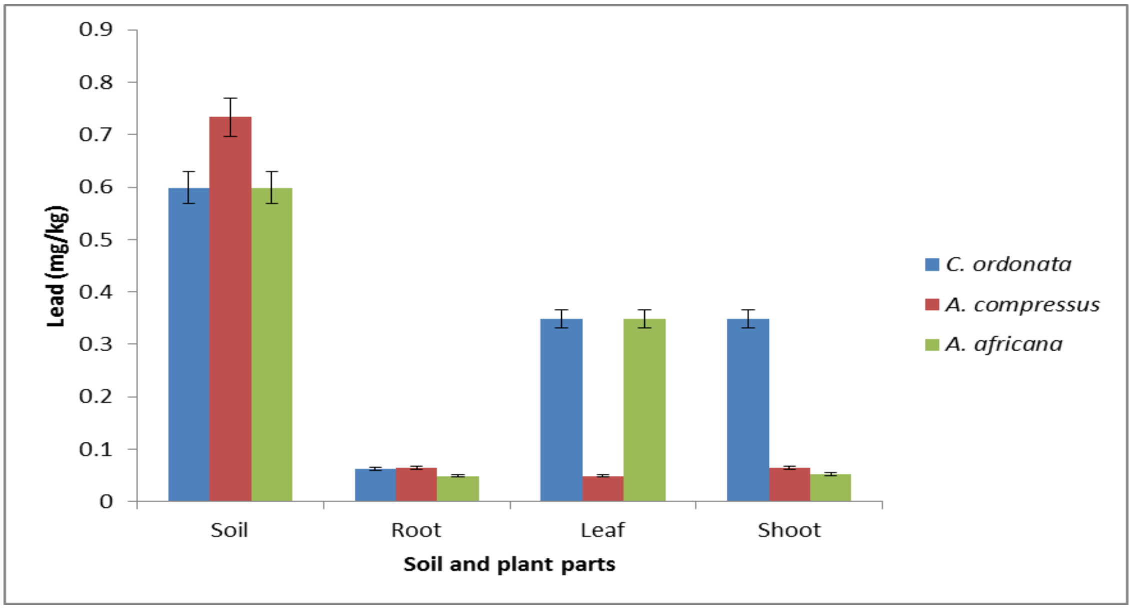

Figure 6: Concentration of lead in soil, root, leaf and shoot of *C. odorata*, *A. compressus* and *A. africana*

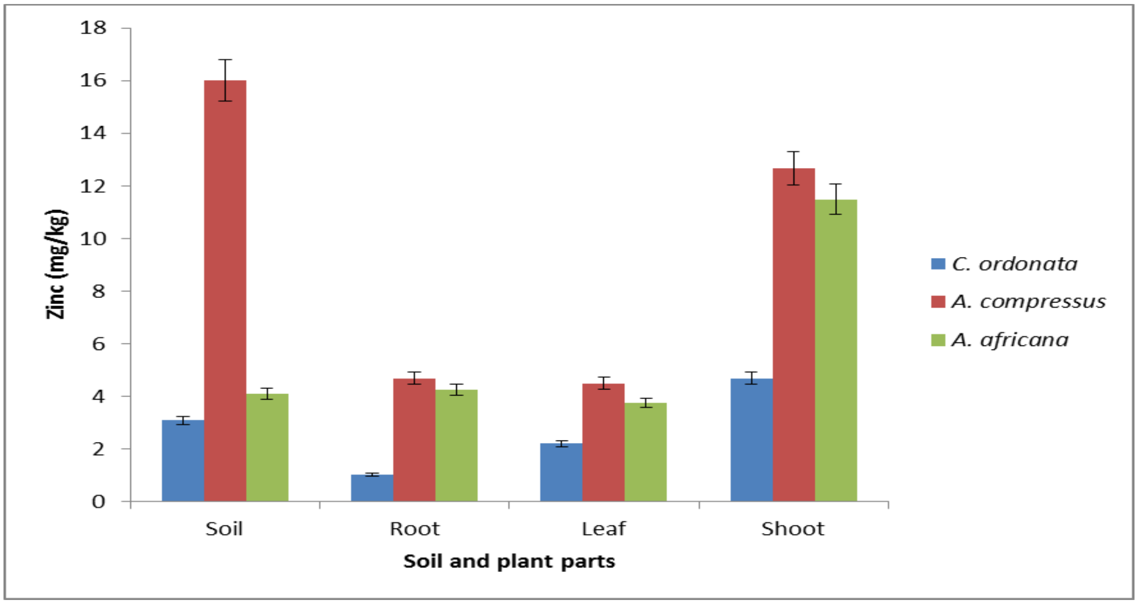

Figure 7: Concentration of zinc in soil, root, leaf and shoot of *C. odorata*, *A. compressus* and *A. africana*

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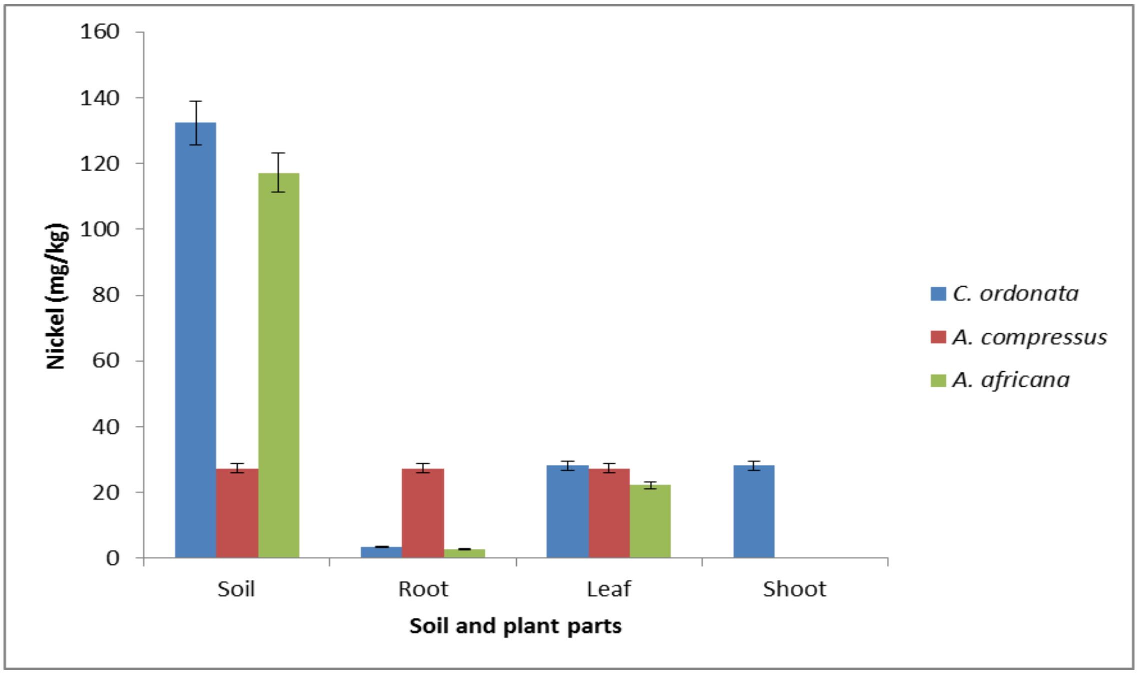

Figure 8: Concentration nickel in soil, root, leaf and shoot of *C. odorata*, *A. compressus* and *A. africana*

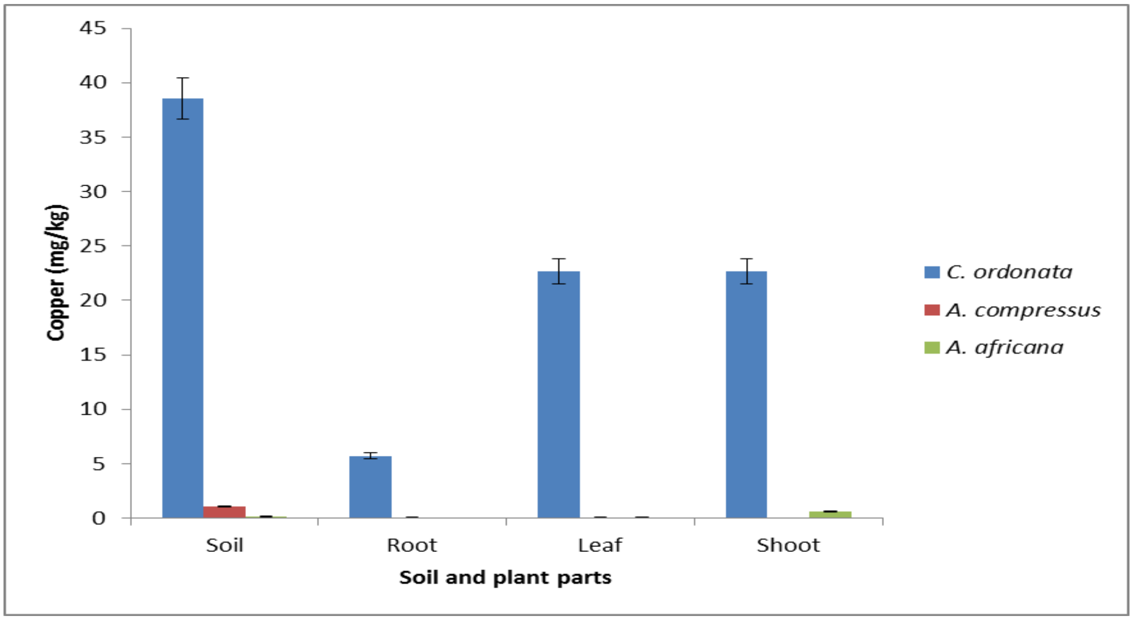

Figure 9: Concentration copper in soil, root, leaf and shoot of *C. odorata*, *A. compressus* and *A. africana*

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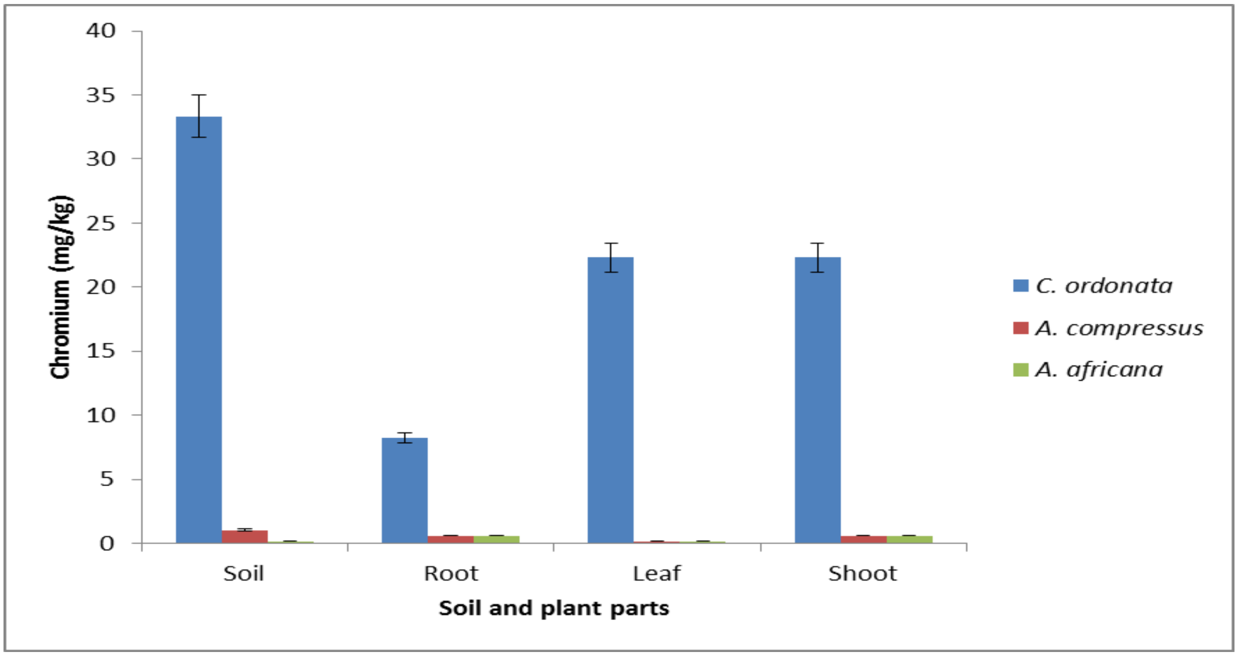

Figure 10: Concentration chromium in soil, root, leaf and shoot of *C. odorata, A. compressus* and *A. africana*

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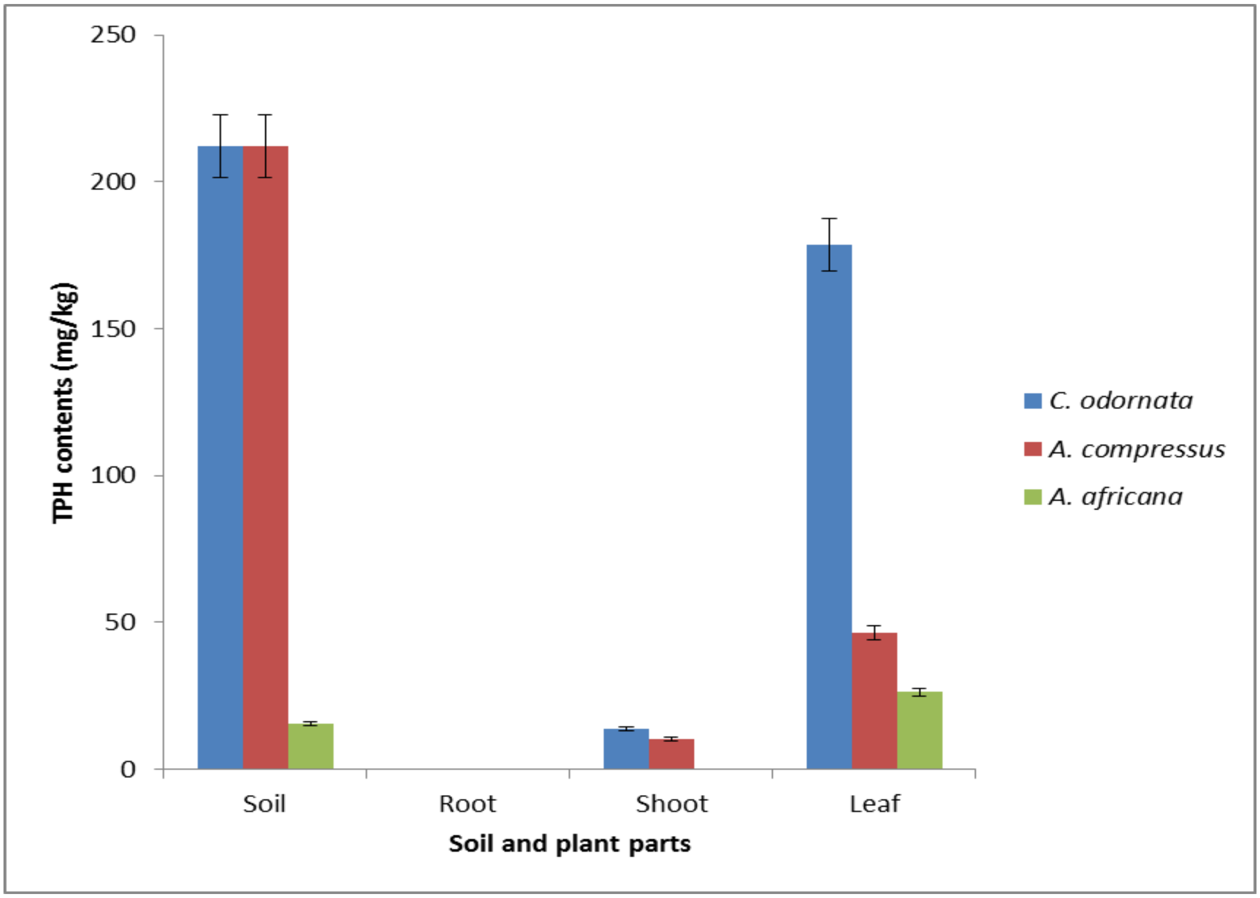

Figure 11: TPH contents in soil, root, leaf and shoot of *C. ordonata, A. compressus* and *A. africana*

Correlation between TPH concentration in soil and plant tissues

In other to understand the relationship between the concentration of TPH in soil and plant tissues, correlation analysis was performed as shown in Figure 4.19. 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 be a result of an increase in the concentration of TPH in the soil 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 the soil increases TPH content in roots and vice versa.

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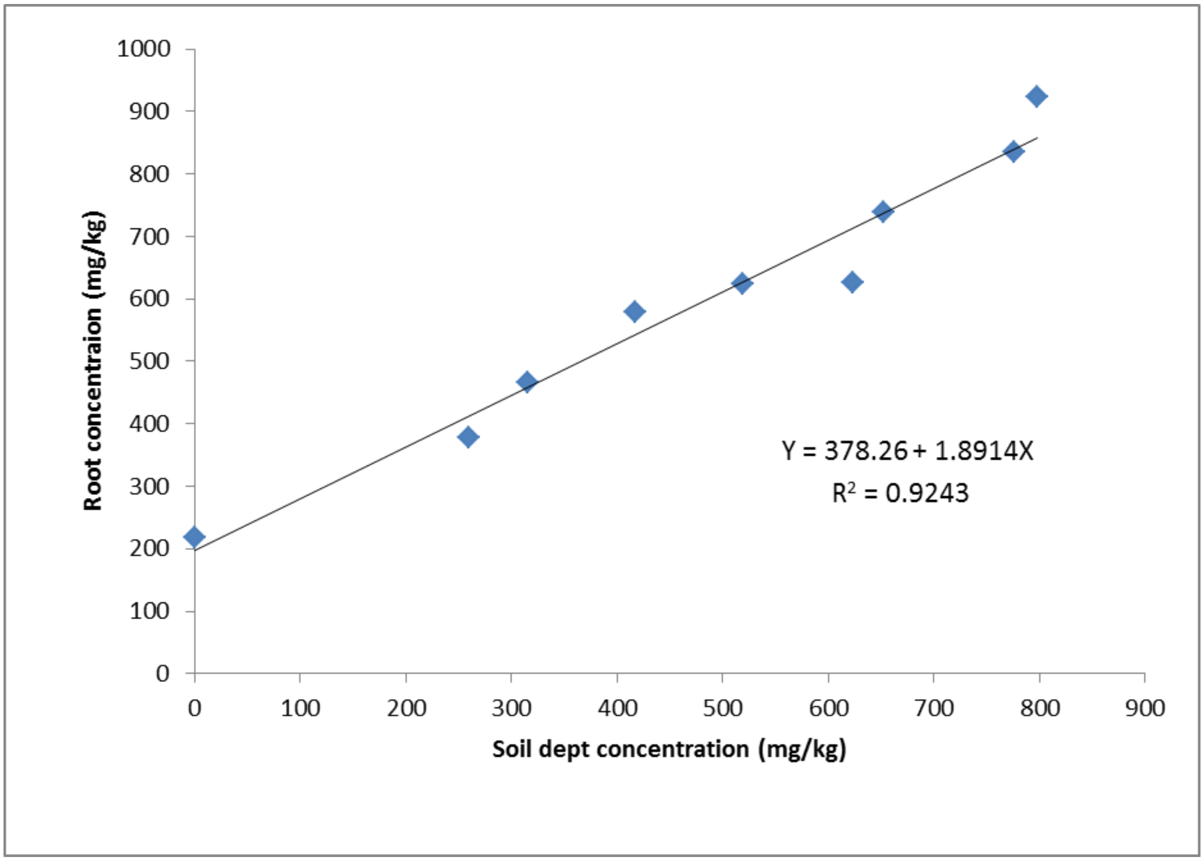

Figure 12. Linear regression between TPH concentration in contaminated soil and root

Discussion

The accumulation of heavy metals in roots shoots and leaves may be an indication that the test plants (*C. odorata, A. africana* and *A. compressus*) posses the potential to remediate sites with low to medium contamination (Olajuyigbe, et al., 2014). This was evidenced by the survival and continued, though concentration-dependent reduction in growth of the test plants, in spent engine oil-contaminated soils (Nwoko et al., 2007). 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 (Figures 1 to 11). This result is similar to the findings of Ekperusi1 and Aigbodion, (2015). Similar growth responses have been reported for seedlings of *Terminalia ivorensis*, *Terminalia superba* and *Khaya senegalensis* (Olajuyigbe & Aruwajoye, 2014). A significant and positive correlation was recorded between TPH concentration in soil and plant tissue. This result is in agreement with the report of Raymond and Harrison (2018). The reason might be that an increase in TPH content in soil resulted in an increased level of TPH in plants.

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, and grow and accumulate biomass in spent engine oil-polluted soil. This underscores 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.

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Cite this article as:
Azorji, J.N., Udebuani, A.C., Igwe, C.E., Nwachukwu, M.O., Nwachukwu, C.U., Nzenwa, P.O., & Igbokwe, M.C. (2023). Phytoaccumulation potentials of three indigenous plant species grown in used engine oil polluted soil. *FNAS Journal of Scientific Innovations*, *5*(2), 17-29.