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PHYTOREMEDIATION OF WASTE ENGINE OIL POLLUTED SOIL IN SOUTHEAST, NIGERIA

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ABSTRACT: *The potentials of B. deflexia and P. scrobiculatum grass species to phytoremediate waste engine oil contaminated soil was investigated. Waste engine oil was added to 4 kg different soil samples to obtain different concentrations on weight basis: 0 % (control), 2 %, 4 %, 7 % and 10 % v/w oil-in-soil and allowed to stand for seven days before transplanting. At the end of 8 weeks of transplanting, the plants were harvested. Both the dried plants parts and the soil samples were subjected to heavy metal analysis for Pb, Zn, Cu and Ni. The result obtained showed that there was increased percentage reduction of heavy metals in the soils. B. deflexia and P. scrobiculatum showed maximum reduction of Ni (99.96%) and Ni (99.76 %) respectively. As the percentage reduction increased the concentrations of the waste engine oil increased. In order words the two grass species studied possess the phytoextraction potential for phytoremediation of waste engine oil contaminated soil.*

KEYWORDS: Phytoremediation, Waste Engine Oil, Polluted Soil, Oil Pollution, Nigeria

INTRODUCTION

Engine oil removed from the crankcase of internal combustion engine is known as waste engine oil (Vazquez-Duhalt, 1989). Before they are put into use, engine oils are made up of performance- enhancing additives (10 to 20% by volume) and a base lubricating oil (a complex mixture of hydrocarbons - 80 to 90% by volume). Alteration of engine oils occurs during use due to the pollution from the combustion products, additives breakdown and the entrance of heavy metals from the wearing of the engine (Vazquez-Duhalt, 1989). Also, in contrast to petroleum pollution, waste engine oil contamination is a world-wide problem as industrial activities and automotive traffic are the main sources (Vazquez-Duhalt, 1989). Waste engine oil spillage at auto-mechanic service workshops in some countries of the world especially Nigeria, have been left unattended to for years and its continual accumulation is of serious environmental concern because of the hazard associated with it (Abdulsalam *et al*., 2011). Spillages from crude oil and its products' affects plants severely by leading to situation whereby essential nutrients like oxygen and nitrogen used by plants for their growth are not available to them. Records have shown that oil pollution leads reduction in germination rate in plants and this situation could be due to the presence of oil which served as a blockage, limiting seeds access to oxygen and water (Adams and Duncan, 2002). As a consequence of movement of chemicals and heavy metals contents of waste engine oil in the ecosystem, they are assimilated and spread into various tissues of plants, animals and human which leads health problem like tremor, anemia, cancer, mutagens and in death at last (Keith and Telliard, 1979; Atlas and Cerniglia, 1995; Lee *et al*., 1999; Boonchan, *et al*., 2000).

Several methods can be used for the rehabilitation of oil-contaminated soils such as engineering techniques based on physical, chemical and thermal processes (Frick *et al*., 1999).The use of plants to remove pollutants from the environment or render them harmless is Phytoremediation (Raskin, 1996).Therefore, as more plants species are subjected to site studies, phytoremediation is being established as a promising technology for a variety of contaminants (Oyibo, 2013). The prevailing climatic condition which encourages growth of plants and microbial activities increases the potential for the technology to be high in the tropics (Oyibo, 2013). The technology is advantageous to tropical environments due to its low-cost component where requisite funds for alternative clean-up measures may be lacking. Investigations of the tropical plants' potential for phytoremediation however, are scarce (Oyibo, 2013).

MATERIALS AND METHODS

Soil Samples

Soil samples used for this study were collected from the experimental farm of the Department of Plant Science and Biotechnology, Michael Okpara University of Agriculture, Umudike, Nigeria. The waste engine oil used was obtained as pooled engine oil from two different major mechanic workshops located in the Mechanic Village, Umuahia, Abia State. The plant materials used were collected from bush fallow located at Umuahia metropolis. Top soil of 0-10cm depth which was collected from a marked area was air dried, sieved through a 2mm mesh gauge (Ogedegbe *et al.*, 2013). 4kg of the soil sample was introduced into different 4 litre perforated plastic buckets after which different concentrations (2%, 4%, 7% and 10%) of waste engine oil denoted as T_1, T_2, T_3 and T_4 respectively, were added to each 4kg soil samples. The mixing was done gradually to ensure thorough and even mixing and the treatment was replicated three times. The untreated soil with 0% waste engine oil served as a control (Tc) (Adenipekum *et al.*, 2009). After thorough mixing, the soil sample were left under the shade for a period of seven days without planting to ensure uniformity of oil, moisture content, air content, constant temperature and effective activities of soil micro-organisms (Oyibo, 2013) after which they were artificially irrigated with water in the experimental farm before the transplanting of the studied plant species and left for natural irrigation.

Plant Materials

The plant species being investigated were propagated by tiller. The tillers of the plants were separated differently and the same height (shoot 15cm) was selected, the roots were soaked in water for 2 days to improve their rooting ability (Brandt, 2003). The tillers were transplanted into different treated soil samples, each with three tillers and allowed to stand for eight weeks. The plant samples were harvested and soil was washed off with water after which they were separated from the shoot and placed in labeled separate envelops for heavy metal analysis.

Determination of Heavy Metal Concentrations in the Plant Samples

Roots and shoot samples of the plant species were oven dried at 65^{o}C for 8 hours, milled in a Thomas Willey Milling Machine, sieved through a 0.5mm sieve and stored in labeled containers. A portion (0.2 g) of the plant samples (root and shoot) of the three plant species were weighed into 150ml conical flask, 5ml of the multiple nutrient extraction reagent (H_2SO_4-selenium powder salicylic acid) solution was added in each flask for digestion and allowed to stand for 20 hours. The plant samples were placed in a hot block plate at 32^{o}C for 2 hours, after which 5ml of 75 % of perchloric acid was added to each sample and re-digested at 60^{o}C. The digestion continued until a clear digest were seen producing a profuse perchloric fumes. The digests were allowed to cool and 50ml of distilled water was added; the samples were filtered and the filtrates were analyzed using AAS to determine the heavy metals (Pb, Zn, Cu and Ni).

Determination of Heavy Metal Contents of the Soil Samples

The heavy metal contents of the soil samples were determined as above.

Statistical Analysis

The results were summarised using Descriptive Statistic Package of Microsoft Excel while one-way ANOVA was used to test for statistical differences among the treatments and Tukey's pairwise comparisons test was performed to determine the location of significant difference ($P<0.05$).

RESULTS AND DISCUSSION

Some of the physico-chemical properties of the soil samples and its texture are presented in Table 1. The control (0 % concentration of waste engine oil) showed that the soil texture is sandy loam based on the USDA textural classes of soil i.e. 69.10 %, 10.20 % and 20.70 % for sand, silt and clay respectively. The soil was acidic with pH of 5.20 while the soil nutrients: phosphorus, calcium, magnesium, potassium and sodium were 32.50 mg/kg-1, 4.00 Cmolkg-1, 2.80 Cmolkg-1, 0.047 Cmol/kg and 0.22 Cmolkg-1 respectively. The percentage organic carbon was found to be 0.6 % which was within the topsoil ranges from 0.5 %- 3.0 % organic carbon for most upland soils. Based on MS1517 organic fertilizer specification (2012), both percentage organic matter and nitrogen have low values required for optimum plant growth values given as 0.60 % and 1.03 % respectively. Cation exchangeable capacity was moderate (8.107 Cmol/kg) which could be attributed to the acidic nature of the soil and the soil texture type. Anion exchangeable capacity increases at low pH but in this case, anion exchangeable capacity is low at low pH, value given as 1.04 Cmol/kg this could be equally attributed to the type of soil texture. The soil texture at different concentrations of waste engine oil remains the same. The acidic nature of the soil was maintained but there was a gradual increase in pH. Soil nutrients (P, Ca and Mg) were lower than control but recorded a gradual increase in their concentrations with treatments. On the other hand, K and Na were equally lower than control but did not show any trend. This could be as a result of oil spillage on soil which resulted in an imbalance in the carbon: nitrogen ratio, which if greater than 17:1 in soils resulted in net immobilization of the nutrients by the microbes leading to loss of soil fertility (Jobson *et al*., 1974). The percent organic carbon was highest value of 2.98 % at 4 % treatment level. The higher organic carbon content of the soil recorded with the treatment may be attributed to the high carbon content of the soil. Similar findings have been reported by Benkacoker and Ekundayo (1995). The percentage nitrogen was lower than the control at 2 % treatment level but increased higher than the control and remain constant from 4 %-10 % treatment levels

(0.112 %). Percentage organic matter was generally higher than the control and the highest values (5.14 %) were recorded in 4 % and 10 % treatment levels. The increment could be equally due to soil simulations with oil. From every indication not all the soil nutrients analyzed were within the range required for plant growth. Exchangeable cation capacity and exchangeable anion were lower at different levels compared to that in the untreated soil (0 %).

Table 1: Physiochemical Properties of the Soil Samples and its Texture

Parameters	Treatments				
	0%	**2%**	**4%**	**7%**	**10%**
% Sand	69.10	69.10	69.10	69.10	69.10
% Silt	10.20	9.70	11.70	10.70	10.70
% clay	20.70	20.50	19.80	19.20	20.20
Texture	SL	SL	SL	SL	SL
pH (H_2O)	5.20	5.88	6.25	6.30	6.60
P Mg/Kg	32.50	18.80	19.80	27.50	30.30
% N	0.098	0.056	0.112	0.112	0.112
% OC	0.60	2.25	2.98	2.84	2.90
% OM	1.03	3.88	5.14	5.00	5.14
Ca Cmol/Kg^{-1}	4.00	1.20	1.60	2.00	2.60
Mg Cmol/Kg^{-1}	2.80	0.60	0.80	1.20	1.20
K Coml/Kg^{-1}	0.047	0.044	0.038	0.054	0.058
Na Cmol/Kg^{-1}	0.22	0.080	0.310	0.22	0.378
EA Cmol/Kg^{-1}	1.04	0.24	0.44	0.56	0.68
ECEC Cmol/Kg^{-1}	8.107	2.542	3.588	3.024	4.416
% BS	87.17	85.67	82.16	86.08	85.95

The concentrations of the heavy metals in the contaminated soils increased with the increased concentrations of waste engine oil (Table 2). The 10 % treatment level recorded the highest concentrations and were significantly different (*P*<0.05) from the control (0 % treatment level). The order of increment for the heavy metals at the 10 % treatment level is as follows: Ni>Pb>Cu>Zn.

Table 2: Initial Heavy Metal Content of Different Concentrations of Waste Engine Polluted Soils One Week after Simulation

	Heavy metal concentration (mg/kg)				
Treated soil	**Pb**	**Zn**	**Cu**	**Ni**	**Mean**
0%	8.6	6.701	5.558	1.503	5.59 ± 1.5^{a}
2%	50.50	33.84	20.51	110.7	53.9 ± 19.9^{ab}
4%	68.48	46.48	32.50	125.7	68.3 ± 20.5^{ab}
7%	90.4	57.13	54.34	141.8	85.9 ± 20.3^{ab}
10%	128.6	60.45	64.38	155.6	102.3 ± 23.7^{b}
Mean	69.3 ± 20.0^{ab}	40.9 ± 9.74^{a}	35.5 ± 10.8^{a}	107.1 ± 27.4^{b}	

a, b = Means with different superscripts across the rows and column are significantly different at p<0.05.

This study showed that there was increased uptake of the heavy metals by the grasses from the soil as the waste engine concentration of heavy metals in the soil (Table 3). At 10% treatment level, *B. deflexia* showed maximum reduction of 99.96 % for nickel while *P. scrobiculatum* showed maximum reduction of 99.76 % for nickel. Considering their percentage mean reduction, the order of reduction for each plant is as follows: Ni>Pb> Cu> Zn for *B. deflexia* and Ni > Pb >Cu> Zn for *P. scrobiculatum*

Table 3: Percentage Reduction of the Heavy Metals from the Soil by the Grass Species

Grass species	Waste engine oil Polluted soil (%)	Percentage reduction in the soil Pb	Zn	Cu	Ni	Mean
	0%	87.07	4.49	66.89	92.81	62.82
B. deflexia	2%	97.62	85.82	92	99.51	93.74
	4%	98.9	90.86	95.54	99.87	96.29
	7%	99.4	94.4	98.38	99.94	98.03
	10%	99.88	96.53	99.21	99.96	98.90
	Mean	96.58	74.42	90.4	98.42	
	0%	76.22	1.51	71.21	91.02	59.99
P. scrobiculatum	2%	97.74	84.66	92.69	98.97	93.52
	4%	99.15	89.22	96.71	99.54	96.16
	7%	99.38	95.03	98.79	99.66	98.22
	10%	99.65	96.84	99.08	99.76	98.83
	Mean	94.43	73.50	91.69	97.79	

The high reduction of these heavy metals by the two grass species could be as a result of low pH of the soil sample because at high pH, metals tend to form metal mineral phosphates and carbonates which are insoluble while at low pH they tend to be found as free ionic species or as soluble organometals and are more bioavailable (Naidu *et al*., 1997; Twiss *et al*., 2001; Resnsing and Maier, 2003; Sandrin and Hoffman, 2007).

The concentrations of the heavy metals in the shoots and roots of the grass species and soil in which they were grown are shown in Figs.1- 4. Fig. 1 showed the uptake of lead by the root and shoot of the grass species and soil. It was observed that the roots of *B. deflexia* accumulated the highest concentration of lead, (25. 00mg/kg) while the lowest accumulation was observed in the soil of *P. scrobiculatum* (0.050 mg/kg). Fig 2 showed the concentrations of the zinc in soil, roots and shoots of the grass species and it was observed that the shoot of *P. scrobiculatum* absorbed the highest concentration (150.02mg/kg) of zinc while the soil of *B. deflexia* indicated the lowest concentration of zinc (0.034mg/kg). Fig. 3 showed the concentration of copper uptake in soil, roots and shoots of the grass species and showed the root of *P. scrobiculatum* to accumulate the highest concentration of copper (5.04mg/kg) while the shoot of *P. scrobiculatum* had the lowest concentration (0.61mg/kg). Fig. 4 showed the concentration of nickel in soil, roots and shoots of the grass species and it was observed that the highest uptake of nickel to be found in the root of *P. scrobiculatum* (0.69mg/kg) while the lowest concentration (0.18 mg/kg) was recorded in the soil where *B. deflexia* was grown.

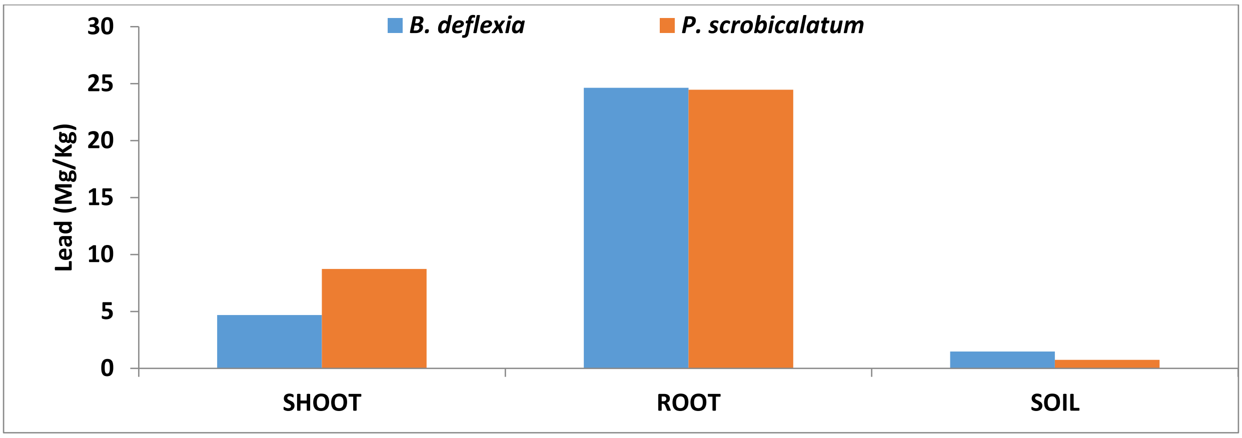

Fig 1: The End Concentrations of the Lead in Soils, Roots and Shoots of the Grass Species.

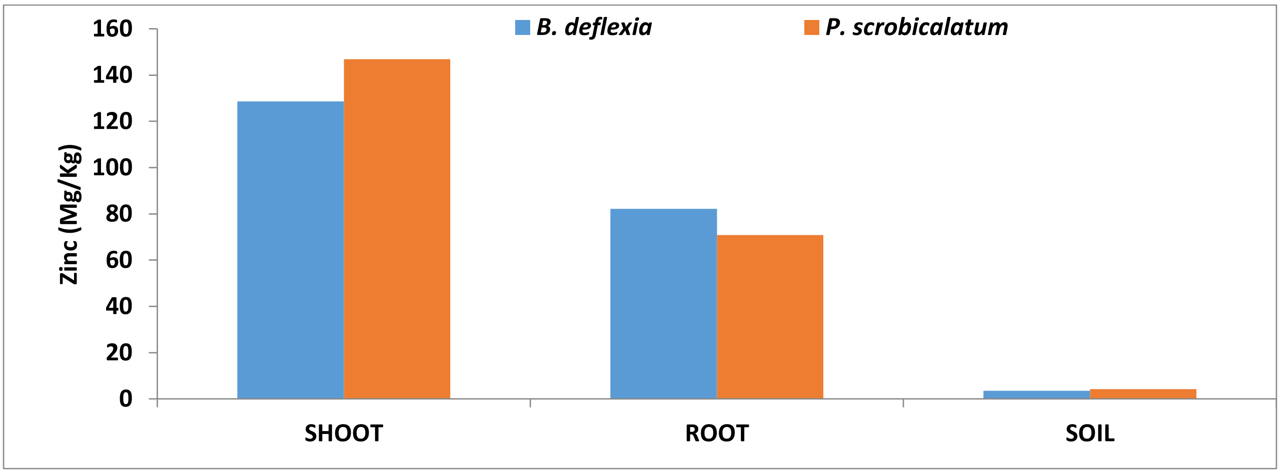

Fig 2: The End Concentrations of the Zinc in Soils, Roots and Shoots of the Grass Species.

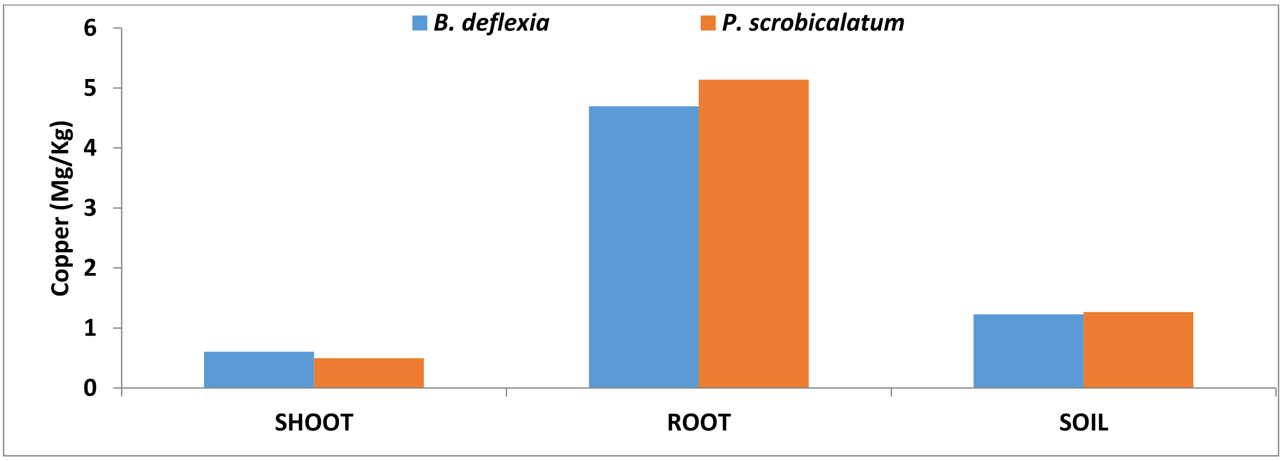

Fig 3: The End Concentrations of the Copper in Soils, Roots and Shoots of the Grass Species.

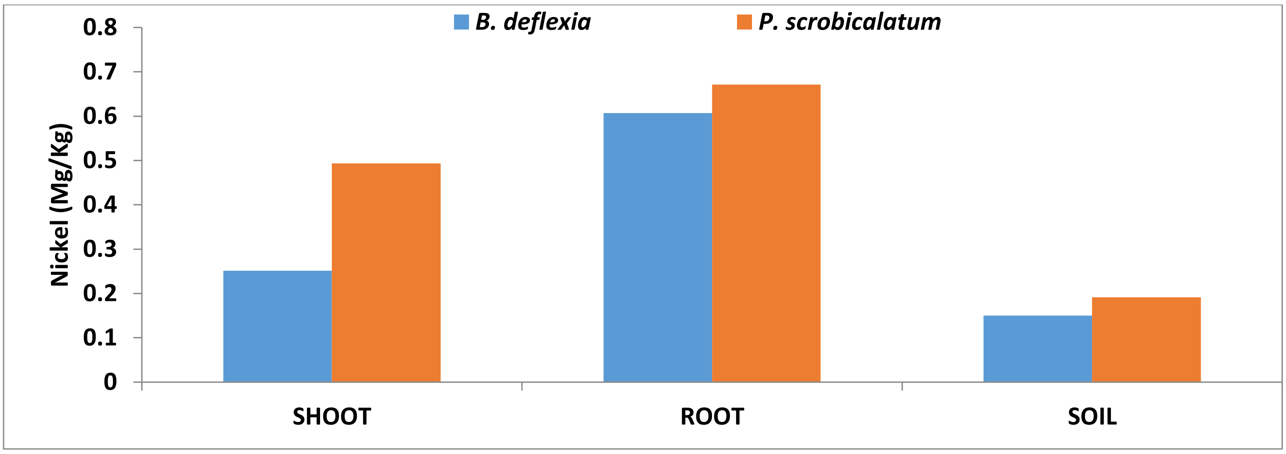

Fig 4: The End Concentrations of the Nickel in Soils, Roots and Shoots of the Grass Species.

These metals were observed to have low concentrations in the soil when compared to the roots and shoots of the grass species generally. Zn was absorbed more in the shoot while Pb, Cu and Ni were highly accumulated in the root. Lowering the pH of the soil decreases the adsorption of heavy metals and thus increases their concentration in the soil solution for uptake by plants (Salt *et al*., 1995; Harter and Naidu, 2001;Garbisu and Alkorta, 2001). Plants absorb various kinds of heavy metals when available in the soil or irrigation water (Fusconi *et al*., 2006). Brooks (1994) observed that possible plants for phytoremediation technology must be tolerant of the focused metal or metals and be efficient in translocation to the harvestable portion of the plant. The observed high level of lead, zinc, nickel and copper in the roots and shoots as compared to the low concentration of the soils may be attributed to the phytoextraction potential of the two grass species studied.

CONCLUSION

In the soils of where *B. deflexia* and *P. scrobiculatum* were grown, it was revealed that there were low concentrations of the four heavy metals studied. Increased percentage reduction in heavy metals in the soils showed that the two grass species accumulated more heavy metals as the concentration of the waste engine oil increased. These findings showed that of the two grass species studied possess the phytoextraction potentials for remediating hydrocarbon polluted soil.

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