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POTENTIALS OF SOME GRASS SPECIES IN THE PHYTOREMEDIATION OF WASTE ENGINE OIL CONTAMINATED SOILS

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ABSTRACT: *This study investigated the potentials of Digitaria horizontalis, Eleucine indica and Sataria barbata grass species in the phytoremediation of waste engine oil contaminated soils. Waste engine oil was added to 4kg 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. The plants were harvested after 8 weeks of transplanting. Dried plants parts and the soil samples were analyzed for heavy metals (Pb, Zn, Cu and Ni). The results obtained showed that there was increased percentage reduction of heavy metals in the soils. D. horizontalis recorded the maximum reduction for Pb and Ni to 99.79% level, E. indica recorded maximum reduction of 99.98% for Ni while S. barbata recorded 99.9% reduction for Ni. Percentage reduction increased as the concentrations of the waste engine oil increased. In conclusion, the three-grass species studied possessed phytoextraction potentials for phytoremediation of waste engine oil contaminated soil.*

Keywords: Waste Engine Oil, Heavy Metals, Digitaria Horizontalis, Eleucine Indica, Sataria Barbata.

INTRODUCTION

Waste engine oil is produced from engine oil which has been contaminated by chemical and physical impurities as a result of usage (Ogedegbe *et al*., 2013). Automotive traffic and industrial activities are the major sources of waste engine oil to the environment and this has been a worldwide problem (Vazquez-Duhalt, 1989). According to Dorsey *et al* (1997), waste engine oil contains accumulated chemicals due to its use as lubricant in engine at high temperature and pressure as it runs inside an engine. Moreso, waste engine oil from motor vehicles contains heavy metals like chromium, aluminum, copper, iron, lead, manganese, nickel, silicon and tin emanated from engine parts as they wear down (Keith and Telliard, 1979). Atuanya (1987) reported that waste engine oil causes breakdown of soil texture followed by soil dispersion. Waste engine oil had inhibitory effects on the growth andearly seedling performance of plants such as *Vigna unguiculata* and *Zea mays* (Kayode *et al*., 2009), hence, there is need to consider petroleum contamination and waste engine oil contamination differently (Vazquez-Duhalt, 1989). So many processes and techniques have been used in remediating environment contaminated with waste engine oil. Phytoremediation as one of the techniques involves the use of plants that can absorb or extract chemical pollutants from the environment thereby decreasing their toxicity in the environment

(Cunnningham *et al*., 1996). Recent techniques of phytoremediation employ plants that grow in pollution zone and as a consequence, plants survival becomes critical. Knowledge of plants tolerance to stress from pollution shows plants ability to change and resist a wide range of chemical pollutants which leads to phytoremediation enhancement. Much have been documented on the phytoremediation of petroleum hydrocarbon contaminated soil (April and Sims, 1990; Gunther *et al*., 1996; Qui *et al*., 1997; Merkel *et al*., 2005; Kirkpatrick *et al.*, 2006; Schwab *et al*., 2006) but none has been reported on the use of *D. horizontalis*, *E. indica* and *S. barbata* in remediating soil contaminated with toxic heavy metal (Pb, Zn, Cu and Ni). These plants were chosen because of their ramified root systems that promote increased rhizophere zone that allows growth increases and microbe activity. Therefore, the objective of this study is to evaluate the potentials of *D. horizontalis, E. indica* and *S. barbata* in remediating waste engine oil contaminated soil.

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 were added to each 4kg soil samples; denoted as T_1, T_2, T_3 and T_4. 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, 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 65ºC 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 tissue samples were placed in a hot block plate at 32°C for 2 hours, after which 5ml of 75 % of perchloric acid was added to each sample and re-digested at 60°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 Content 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 range of 0.5 - 3.0 % for most upland soils. Based on MS1517 organic fertilizer specification (2012), both percentage organic matter and nitrogen had low values (0.60 % and 1.03 % respectively) required for optimum plant growth. 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 study, anion exchangeable capacity was low (1.04 Cmol/kg) at low pH which could also be attributed to the soil texture. The soil texture at the different treatments of waste engine oil remained the same. The acidic nature of the soil was maintained but there was a gradual increase in the pH with the increasing concentration of waste engine oil; indicating the ability of waste engine oil to increase soil pH. Soil nutrients (P, Ca and Mg) were lower than control (0%) but recorded a gradual increase in their concentrations with treatments. On the other hand, K and Na were equally lower than control but didn't show any trend. This could be attributed to the effect of the waste engine oil, which resulted in an imbalance in the carbon: nitrogen ratio; 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 percentage organic carbon recorded the highest value of 2.98 % at 4% treatment level. The higher organic carbon contents of the soil recorded with the treatments could be attributed to the high carbon content of oil. Similar findings were recorded by Benkacoker and Ekundayo (1995). The percentage nitrogen was lower than the control at 2% treatment level but increased higher than the control and remained 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. Some of the soil nutrients evaluated were not within the range required for plant growth. Exchangeable cation capacity and exchangeable anion were lower at the different treatment levels compared to 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$_2$O)	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 the 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 oil concentration increased; leading to the reduction in the concentration of the heavy metals in the soil (Table 3). At 10% treatment level, *D. horizontalis* recorded maximum reduction of 99.99% for lead and nickel; *E. indica* recorded maximum reduction of 99.98% for nickel while *S. barbata* recorded maximum reduction of 99.99% for nickel. Based on the mean percentage reduction, the order of reduction for each plant is as follows: *D. horizontalis* (Ni>Pb> Cu>Zn), E. *indica* (Ni > Cu >Pb> Zn) and *S. barbata* (Ni > Cu >Pb> Zn).

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**
D. horizontalis	0	84.76	10.76	69.41	90.69	63.91^a
	2	97.9	99	93.7	99.96	97.64^b
	4	99	94.62	96.8	99.97	97.60^b
	7	99.5	96.32	98.2	99.98	98.50^b
	10	99.9	97.35	98.76	99.99	99.00^b
	Mean	96.21	70.61	91.37	98.12	
E. indica	0	64.63	29.86	79.31	83.7	64.38^a
	2	94.85	89.54	94.64	99.8	93.96^b
	4	97.85	93.12	96.86	99.89	96.93^b
	7	98.73	96.45	98.23	99.97	98.35^b
	10	99.19	96.94	99.15	99.98	98.82^b
	Mean	91.05	81.18	93.64	96.67	
S. barbata	0	65.85	17.62	73.01	70.73	56.80^a
	2	95.64	87.44	93.17	99.83	94.02^b
	4	97.88	93.12	95.91	99.94	96.71^b
	7	99.07	94.93	98.01	99.98	98.05^b
	10	99.94	97.52	98.69	99.99	99.04^b
	Mean	91.68	78.13	91.76	94.09	

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

The high reduction of these heavy metals by the three grass plant 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 metals in the shoots and roots of the grass species and soils where they were grown are shown in Figs. 1 – 4. Fig. 1 showed the uptake of lead by the roots and shoots of the grass species; it was observed that the roots of *E. indica* accumulated the highest concentration of lead (31. 22mg/kg) while the lowest concentration (0.070 mg/kg) was recorded in the soil where D. *horizontalis* was grown. Fig. 2 showed the concentrations of the zinc in soils, roots and shoots of the plant species and it was observed that the shoot of *S. barbata* absorbed the highest concentration (149.08mg/kg) of zinc while the soils where *D.*

horizontalis and *E. indica* were grown recorded the lowest concentration of zinc (3.064mg/kg). Fig. 3 showed the concentration of copper in soils, roots and shoots of the plant species; it was observed that the root of *D. horizontalis* to accumulate the highest concentration of copper (5.02mg/kg) while the soil where *S. barbata* was grown had the lowest concentration (0.53mg/kg). Fig. 4 showed the concentration of nickel in soils, roots and shoots of the grass species; it was observed that the highest uptake of nickel was in the root of *D. horizontalis* (0.60mg/kg) while the lowest concentration (0.05 mg/kg). was recorded in the soil where *E. indica* was grown.

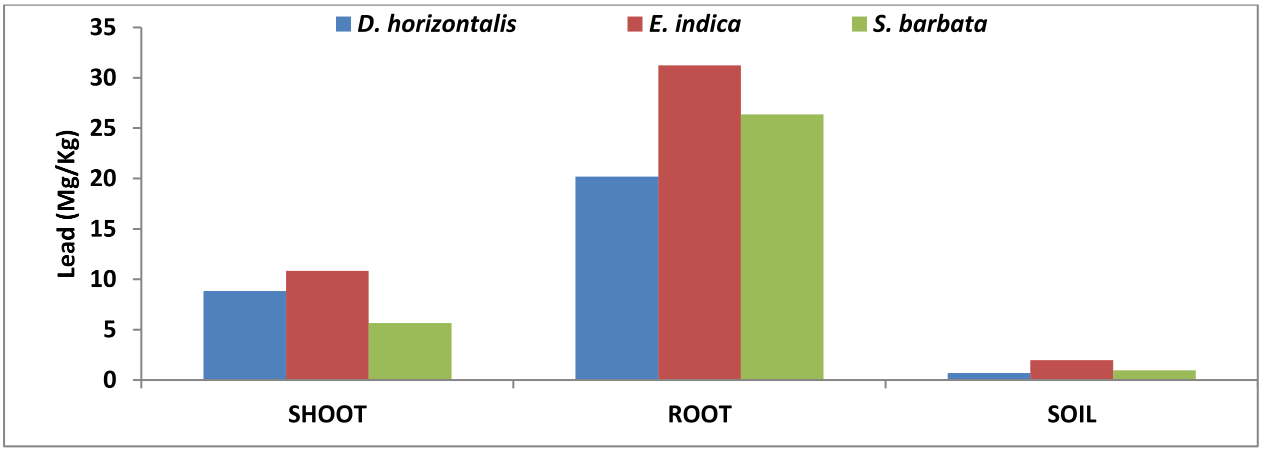

Fig.1: The End Concentrations of the Lead in Soils, Roots and Shoots of the Grass Species.

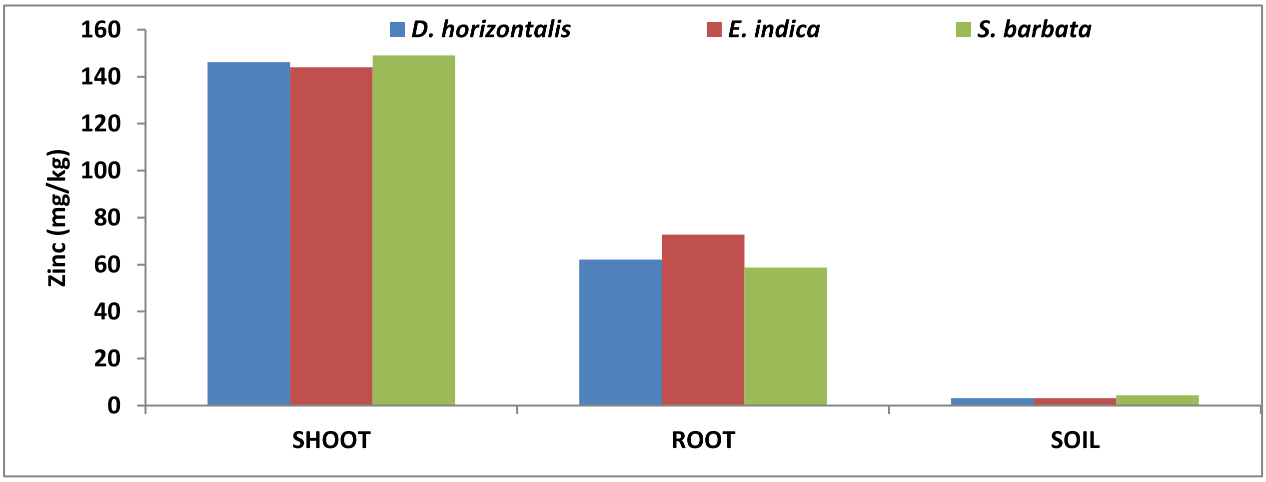

Fig. 2: The End Concentrations of the Zinc in soils, Roots and Shoots of the Grass Species.

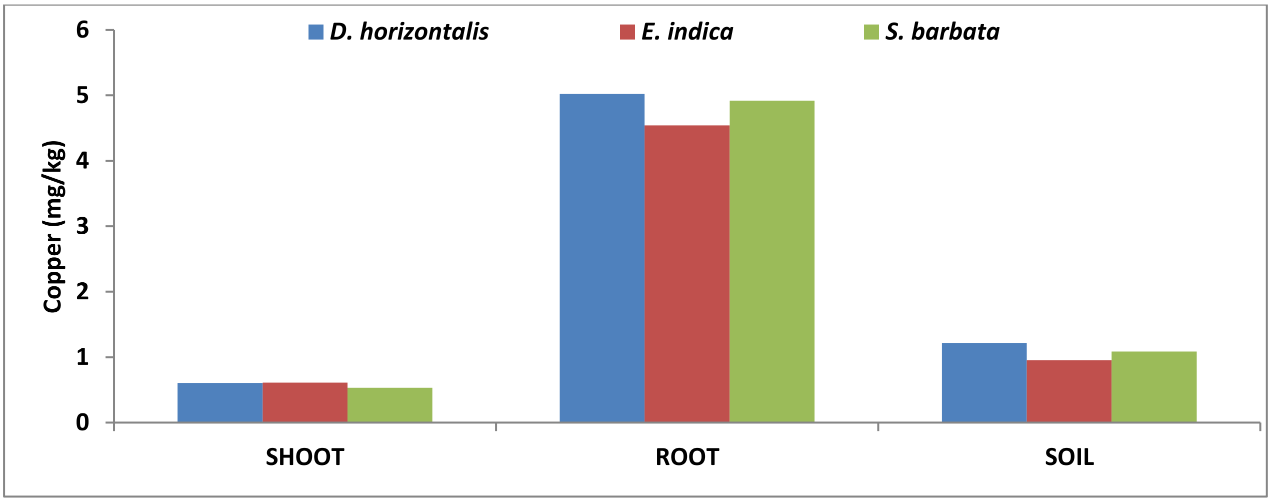

Fig. 3: The End Concentrations of the Copper in Soils, Roots and Shoots of the Grass Species.

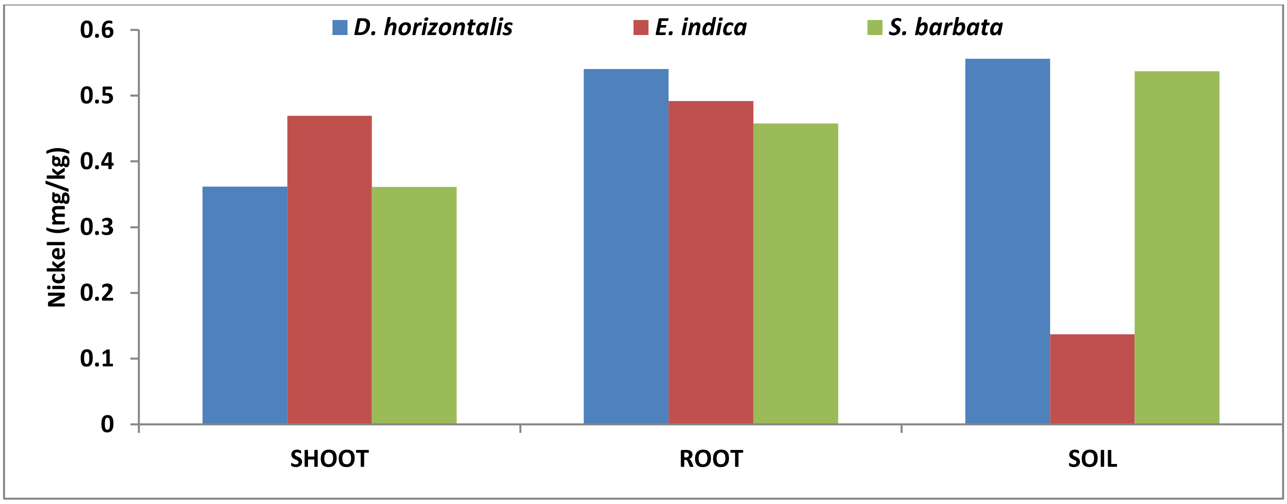

Fig. 4: The End Concentrations of the Nickel in Soils, Roots and Shoots of the Grass Species.

Generally, low concentrations of these metals were observed in the soil when compared to the roots and shoots of the plant species. Pb, Cu and Ni were highly accumulated in the roots while Zn accumulated more in the shoots. This could be probably due to some physiological barriers against metal transport to aerial parts, while some are easily transported to other parts. Garbisu and Alkorta (2001) reported that some trace metals like lead were accumulated in roots while some others are easily transported to other parts. Omosun *et al* (2009) also recorded high concentration of lead and nickel in root of *Mucana* species when compared to copper. The high uptake of zinc in the shoot of the plant species could be due to high dissolution of zinc in soil moisture and as an essential micronutrient required for plant growth development and reproduction (ITRC, 2009). Some other non-essential elements can also be taken up; this could be the reason for high concentrations of Pb, Zn, Cu and Ni in both the roots and shoots of the plant species than in the soil (ITRC, 2009). However, high accumulation of these metals in the roots and shoots of the plant species could be attributed to the phytoextraction ability of the grass species studied. The potential plants for phytoremediation must be tolerant to the metal or metals under investigation and also be efficient in translocation to the harvestable portion of the plant (Brooks, 1994).

CONCLUSION

The grass species studied were tolerant to waste engine oil contamination to a varying degree. This study revealed that there were low concentrations of the heavy metals investigated in the soils where *D. horizontalis*, *E. indica and S. barbata* were grown. The grass species were able accumulate more heavy metals as the concentrations of the waste engine oil increased. It can be concluded that the grass species studied have phytoextraction potentials and can be used for the phytoremediation of waste engine oil contaminated soils.

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