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Effectiveness of Vetiver (Vetiveria Zizanioides) in Heavy Metal and Total Hydrocarbon Content Removal from Spent Oil Contaminated Soil in Portharcourt and Obio/Akpor Nigeria

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Abstract

A pot experiment was conducted at University of Port Harcourt Teaching and Research farm to examine the effectiveness of vetiver grass to remove heavy metals: (Zn), Nickel (Ni) and Lead (Pb) and Total Hydrocarbon Content (THC) from spent oil contaminated soil. Composite soil samples were collected randomly at a depth of 0-15, 15-30 and 30-45 cm from around Elikohia and Choba automobile workshop respectively in Rivers State, Nigeria. A control soil samples at same depths were taken at 100 meters awa y from uncontaminated areas. Ten (10) kg each of harmonized soil samples of contaminated without vetiver (cont no vetiver), contaminated remediated with vetiver (cont+vet) were placed in a 10 litre perforated plastic buckets. Two slips (seedlings) of vetiver grass were transplanted per bucket. Twelve weeks later, soil, roots and shoots of vetiver plants were analysed for THC, Zn, Ni and Pb. Results of the study on THC, Zn, Ni and Pb showed significant ($P<0.05$) increased between the contaminated soil over control. Remediation of the soil with vetiver grass significantly ($P<0.05$) reduced the contamination of the soil from 452.07 and 562.73mg/kg in contaminated without vetiver (cont no vet) to 235.83 and 241.80mg/kg for THC in cont + vet; 1885.47 and 2033.03 to 929.13 and 1013.70mg/kg for Zn in cont no vet and cont + vet; 1023.53 and 1355.90 mg/kg to 631.70 and 642.63mg/kg for Ni and 1761.9 and 1854.47 to 935.60 and 968.13 mg/kg for Pb in cont no vet and cont + vet respectively for Choba and Elikohia respectively. The THC and heavy metals in the soil decreases with increase in depth of soil profile in the two sites studied. The uptake of THC, Zn, Ni and Pb were observed to be significantly ($P<0.05$) higher in the roots than the shoots portions of the plant in all the depths in the two sites. The order of uptake for heavy metals was Zn>Pb>Ni in both roots and shoots in both Choba and Elikohia. The results therefore showed that vetiver grass was effective in removing significant quantity of THC, Zn, Pb and Ni contents from spent automobile contaminated soils.

Keywords: THC, Heavy Metals, Spent Oil Contaminations, Vetiver Grass

Introduction

Spent oil or spent engine oil is obtained when servicing of used automobile and generator engines by draining off the used oil which are usually discarded. In Nigeria, this used oil is indiscriminately disposed into water, drains, gutters, open vacant land and farm land (Anoliefo and Vwioko, 2001) [2].

It involves changing lubricating oil, servicing and greasing of motor parts and replacement of worn out parts. The oil contains heavy metals and potentially toxic polycyclic aromatic hydrocarbon (Shar *et al*., 2009) [19].

These oil contained some toxic elements such as cadmium, barium, vanadium, aluminum, nickel, iron, zinc and polycyclic aromatic hydrocarbon (Dominquez-Rossado *et al*., 2004 and Wang *et al*., 2000) [9, 25]. The major source of automobile wastes in Port Harcourt, Nigeria is motor vehicle servicing center popularly known as motor mechanic workshops which are found in most parts of the country.

Indiscriminate disposal of these used oil on the environment (soils, water bodies) pose major risk on agriculture. Disposal of spent oil from automobile and other petroleum by-products are serious concern due to their persistence and carcinogenicity. They are mostly non-biodegradable and can be transformed from one oxidation or organic complex to another (Garbisu and Alkorta, 2003) [12]. The contaminated environment with toxic substances may affect its ability to provide good habitat for soil organisms, crop growth and human health. Pollution of the soil with petroleum products leads to build up of essential organic carbon, phosphorus, calcium and magnesium and non-essential (lead, zinc, cobalt and copper) elements in the soil which are eventually translocated to plant tissues (Vwioko *et al*., 2006) [24].

Phytoremediation is one of the conventional remediation techniques available for decontamination of contaminated soils. It involves use of green plants and micro-biota /agronomic techniques to remove, contain or render harmless environmental contaminants (Cunningham, 1996) [8]. Sharma *et al*., (2020) [20] in their study reported that metal accumulator plants have phytoremediation potential to reduce different pollution parameters after growth on sludge and so can be use as biotechnological tools for eco-restoration of polluted sites.

Plant species used for phytoremediation should have high tolerance for toxicity of high accumulation capacity able to extract and brake down, transpire heavy metals or impurities from air/water through the aerial organs. Vetiver grass (Vetiveria zizanioides) has been documented to have high resistance to toxicity able to survive in high concentration of heavy metals (Shu, 2001, Truong, 1999 [21]). The roots can absorb and accumulate several times some heavy metals present in the soil (Truong and Baker, 1998) [22].

The study is aimed at (i) Assessing the ability of vetiver grass to clean up spent oil polluted sites (ii) To translocate heavy metals and hydrocarbon from the soil to the roots and shoots of the plants.

Methods

The experiment was conducted at the University of Port Harcourt Teaching and Research farm, department of crop and soil science. The area is situated between latitude $4^0$54' N and longitude $6^0$55' East of the equator on an elevation of 20meters above sea level.

The mean maximum monthly temperature is 31.29°C, the minimum is 21.80°C (Uko and Tamunobereton-Ari, 2013) [23], while annual monthly monthly rainfall is (Uko and Tamunobereton-Ari, 2013) [23]. The rainy season is from April to October while dry season from November to March. Relative humidity varies between 35 to 90% depending on the period of the year.

Location for Soil Sample Collection

Soil samples used for the study were collected from (i) Elikohia mechanic workshop (site 1) and (ii) Choba mechanic workshop (site 2) in Port Harcourt and Obio/Akpor Local Government Area of Rivers State, Nigeria respectively. Composite samples of spent oil contaminated soils were collected randomly at a depth of 0-15, 15-30 and 30-45cm from the two sites respectively and uncontaminated samples (control) at 100 meters away from the two sites with shovel.

Soil Sample Preparation and Planting of Vetiver Grass

The experiment was carried out using perforated plastic pots. Ten (10kg) each of harmonized composite soil samples of depths (0-15, 15-30 and 30-45)cm of contaminated and no vetiver, contaminated and remediated with vetiver and control soil samples taken 100 meters away from the sites were placed into 10-liter perforated plastic buckets. The experiment was replicated thrice giving a total of 18 pots.

The pots were watered thrice weekly with 200mls of water through a watering can each. Two weeks later, vetiver grass (Vetiveria zizanioides) obtained from National Root Research Institute, Umudike, Abia State, Nigeria were transplanted. The vetiver grass was propagated by slips. The slips were ripped off the main clump and planted into the pots like seedlings. Two seedlings were planted per pot. Emerging weeds were removed by hand pulling. The experiment was 3×2×3 completely randomized design (CRD) consisting of three depths, two sites replicated thrice making a total of 18 pots. The experiment was left for a period of twelve weeks.

Soil Sampling and Data Collection

Composite soil samples uncontaminated (control), contaminated and no vetiver, contaminated and remediated with vetiver were collected from each of the pots, labeled and air dried at room temperature in the laboratory. The samples were pulverized with mortar and pestle, sieved in a 2mm mesh screen and sent to the laboratory for the determination of the following parameters; zinc (Zn), nickel (Ni), lead (Pb) and total hydrocarbon (THC).

Similarly, composite plant tissue (roots, stems leaves) samples were collected, washed to remove sand and dust and dirt, air-dried at room temperature, ground and taken to the laboratory for heavy metal (Ni, Pb and Zn) analysis.

Laboratory Analysis

Soil sample for heavy metals (Zn, Ni and Pb) were extracted by wet digestion method of Benton, (2001) [4], 0.5g of soil samples were weighed into 50mls conical flask, 10mls of nitric acid (HNO_3) was added and heated to dampness in fume cupboard, the samples were removed and allowed to cool to 25^0c room temperature before 10mls of perchloric acid ($HCLO_4$) was added to it. The samples were then removed from the fume cupboard, allowed to cool and made up to 50ml mark with distilled water.

The digest was filtered with No 42 whatman filter paper into transparent plastic containers for Atomic Absorption Spectrophotometer (AAS) elemental reading. AAS variance spectr AA 220FS model was used to read the concentration values of (Zn, Ni and Pb) in the soil digest following Horneck and Hanson method in Benton, (2001) [4]. The data generated were subjected to statistical analysis using Analysis of Variance (ANOVA). Duncan test was used to test the data.

The THC was estimated using the method of Odu *et al*., (1985) [17]. 10g portion of the soil sample was shaken with 10mls of carbon-tetrachloride. The total hydrocarbon content was extracted and determined by the absorbance of the extract at 420nm spectrophotometer. Standard curve of the absorbance of different known concentrations of equal amount of spent oil in the extract was first drawn after reading from the spectrometer.

Result and Discussion

Results of the study on the effectiveness of vetiver grass to remove THC and heavy metals from spent oil contaminated soils are as presented in table 1 below. The total hydrocarbon content (THC) of the soil varies from 452.07 and 564.73mg/kg in spent oil contaminated soil with no vetiver grass to 0.42 and 0.43mg/kg in control samples in all the depths on the two sites (Choba and Elikohia) respectively.

Table 1: Effect of Remediation on THC and Heavy Metal in Soil of Choba and Elikohia

Depth	Treatment	Site	Zn	Ni	Pb	THC
0-15	Control	Choba	9.05	2.48	4.37	0.98
		Elikohia	10.30	2.60	5.28	0.93
	Cont no vet	Choba	1885.47	1023.53	1761.9	452.07
		Elikohia	2033.03	1355.90	1854.45	564.73
	Cont +vet	Choba	929.13	631.70	935.6	235.83
		Elikohia	1013.70	642.65	968.10	241.80
15-30	Control	Choba	7.47	2.07	4.05	0.65
		Elikohia	8.63	2.15	4.50	o.60
	Cont no vet	Choba	1353.43	986.7	1240.90	432.0
		Elikohia	1765.73	1270.33	1572.62	498.37
	Cont +vet	Choba	886.83	465.35	820.23	214.9
		Elikohia	994.57	552.01	860.12	201.24
35-45	Control	Choba	6.72	1.25	3.18	0.40
		Elikohia	7.25	1.83	3.14	0.47
	Cont no vet	Choba	1116.17	859.23	819.05	340.00
		Elikohia	1424.57	892.40	873.20	363.67
	Cont +vet	Choba	741.82	510.26	711.90	173.22
		Elikohia	723.40	494.19	752..25	160.00
LSD			1.314/2.275	1.314/2.276	1.605/2.780	

The result revealed a significant ($P<0.05$) increase in THC contaminated soil over control. The significant increase in THC over control could possibly be due to the presence of carbon present in spent engine oil. Mansur *et al*., (2003) [16] reported that percentage carbon (organic and inorganic) represents the extent of hydrocarbon in the soil. The greater the organic content, the higher the level of organic pollutants present.

Remediation of the spent oil contaminated soil with vetiver grass significantly ($P<0.05$) reduced the content of THC from contaminated no vetiver (452.07 and 562.73mg/kg) to 235.83 and 241.80mg/kg in contaminated + vetiver grass in both Choba and Elikohia sites respectively. The result showed that vetiver grass has the ability to degrade spent oil contaminated soil. This corroborates with the report of (Chukwumati and Omovbude, 2020; Banks *et al*., 1999 and Biondini *et al*., 1988) [7, 23, 5] who in their various studies recognized the important of plants in the degradation of crude oil contaminated soil. The THC of the soils were significantly ($P<0.05$) reduced as you moved down the soil profile in the two sites (Choba and Elikohia). This is in line with the observation of (Alinnor *et al*., 2014) [1] who inferred that contamination of soil with total petroleum hydrocarbon decreased with increased in depth of soil profile.

The results also showed an increase in THC contamination in all the soil depths in Elikohia over Choba site. This could possibly be due to high volume of vehicles found at Elikohia mechanic workshop due to its location at the heart of Port Harcourt City compared to Choba with lower volume. The THC obtained in the two sites was above the 50mg/kg target limit by DPR in agricultural soils as cited by (Edori *et al*., 2020) [10].

The ability of vetiver glass to uptake THC on its roots and shoots are presented in tables 2 and 3 below.

Table 2: Heavy Metal Uptake in Plant Root at Choba and Elikohia

Depth	Treatment	Site	Zn	Ni	Pb	THC
0-15	Control	Choba	1.23	0.42	1.07	0.087
		Elikohia	2.07	0.67	1.30	0.167
	Cont no vet	Choba	561.43	168.1	287.53	452.07
		Elikohia	618.50	213.37	350.7	562.73
	Cont + vetiver	Choba	175.83	83.23	147.43	126.57
		Elikohia	151.17	86.53	103.10	137.28
15-30	Control	Choba	0.83	0.25	0.77	0.058
		Elikohia	1.23	0.06	0.90	0.100
	Cont no vet	Choba	487.53	138.40	246.09	439.47
		Elikohia	562.97	182.22	303.15	498.35
	Cont + vetiver	Choba	135.57	73.50	108.27	119,09
		Elikohia	124.6	70.27	83.41	128.90
30-45	Control	Choba	0.62	0.17	0.55	0.033
		Elikohia	0.94	0.03	0.60	0.075
	Cont no vet	Choba	412.57	122.03	208.50	432.08
		Elikohia	540.70	186.61	286.00	488.20
	Cont + vetiver	Choba	116.43	51.1	78.66	112.51
		Elikohia	114.89	40.73	64.30	121.07
LSD Depth			1.124	1.006	1.775	0.464
P value			.946	1.006	1.775	0.803
LSD for trt			1.946	1.742	3.074	0.4635

There was no significant (P>0.05) difference in control samples between the two sites (Choba and Elikohia) in all the depths, but significant (P<0.05) difference were observed in the uptake of THC in plant roots and shoots (Table 3) between the spent engine oil contaminated soil with no vet and soil contaminated remediated with vetiver grass in all the depths on the two sites (Choba and Elikohia) respectively.

The significant increase in the uptake of THC in vetiver grass roots and shoots from spent engine oil contaminated with no vetiver and spent oil contaminated soil remediated with vetiver indicating that the more the contaminants (THC) in the soil, the higher the plant uptake of the contaminants (THC) in their tissues (roots and shoots). This simply means that remediating of spent oil contaminated sites with vetiver grass influences greatly the rate of contaminants (THC) removal. This observation agrees with the findings of (Chukwumati and Kamalu, 2021 [6], Bank *et al*., 1999 and Lee and Bank 1993) who reported that hydrocarbon depending on their chemical properties could be absorbed in the plant roots and shoots and accumulate in the plant tissues, volatilize and metabolized by plants.

The quantity of THC uptake in plant roots were significantly (P<0.05) higher than those from the shoots in all the depths in the two sites (Choba and Elikohia) investigated.

The contents of THC uptake in vetiver roots and shoots were significantly (P<0.05) higher in Elikohia than Choba mechanic workshop. The reason could be possibly due to the volume of vehicles present at Elikohia than Choba as noted above. The results also revealed that the concentration of THC decreases with increase in the depth of soil profile in the two sites studied.

Table 3: Heavy metal uptake in plant shoot

Depth	Treatment	Site	Zn	Ni	Pb	THC
0-15	Control	Choba	0.082	0.04	0..06	0.020
		Elikohia	0.117	0.06	0.08	0.047
	Cont no vet	Choba	88.37	42.6	33.47	452.97
		Elikohia	101.97	48.80	42.33	562.07
	Cont + vet	Choba	47.27	28.17	14.23	73.12
		Elikohia	55.36	22.50	16.51	88.14
15-30	Control	Choba	0.060	0.03	0.04	0.010
		Elikohia	0.075	0.02	0.06	0.017
	Cont no vet	Choba	62.77	34.00	25.30	439.47
		Elikohia	79.33	37.97	35.57	498.35
	Cont + vet	Choba	32.13	20.47	11.60	66.23
		Elikohia	38.47	18.84	13.52	72.08
30-45	Control	Choba	0.45	0.02	0.02	0.01
		Elikohia	0.56	0.02	0.04	0.011
	Cont no vetiver	Choba	45.10	28.77	20.35	432.08
		Elikohia	62.03	35.74	28.00	488.20
	Cont + vetiver	Choba	18.83	14.71	9.50	60.01
		Elikohia	23.30	14.55	10.23	69.25
LSD Trt depth			0.405	0.887	0.779	0.125
LSD Trt site			0.701	1.536	1.349	0.216
P. Value						

Heavy Metal Uptake

Result of the study on heavy metals (Zn, Pb and Ni) uptake on vetiver tissues (roots and shoots) is presented as shown in table 3 above. The result showed that Zn, Ni and Pb concentration in soils in plant shoots were significantly higher in spent oil contaminated soils over control (Table 3). Significant (P<0.05) difference were observed in the concentration of these heavy metals in spent oil contaminated soil with no vetiver against control in both sites (Elikohia and Choba) in all the depths. These tallies with the findings of (Chukwumati and Kamalu, 2021; Igwe and Nwachukwu, 2015 and Truong and Baker, 1998) [6, 13, 22] who reported an increase in the contents of Zn, Pb, Ni, Co and Fe in contaminated soil over control in their work.

Remediation of the soil with vetiver grass significantly (P<0.05) reduced the concentration of Zn, Ni and Pb in the soil by up taking the heavy metals in its roots and shoots. This agrees with the findings of Chukwumati and Kamalu, 2021 [6] who reported a significant reduction in some heavy metals in their study on a crude oil contaminated soil. Vetiver grass was able to remove heavy metals by absorbing them in their roots and shoots portion. Similarly, Gallego *et al*., (2002) [11] and Zomoza *et al*., (2002) [27] reported in their work that plants grown on polluted soils contain elevated levels of heavy metals in their tissues.

Studies have shown that plants naturally have the capability to extract elements from the soil and translocate them to its roots, shoot and leaves portion from contaminated sites (Jordao *et al*., 2006, Ximenez-Embum *et al*., 2002) [14, 26].

Uptake of the three heavy metals (Zn, Pb and Ni) studied were significantly (P<0.05) higher in the roots than the shoot of vetiver grass in all the depths in the two sites investigated. Similar observation was reported by Roongtanakiat *et al*., 2007 who in their study on industrial waste water using three vetiver ecotypes observed that the vetiver concentrated more of the heavy metals in their roots than the shoots. The concentration of the heavy metals in the plant tissues (roots and shoots) were significantly (P<0.05) higher at Elikohia than Choba site and decreases with an increase in soil profile depths.

The order of uptake of the three heavy metals (Zn, Pb and Ni) was: Zn>Pb>Ni in both the roots and shoots in the two sites studied. Based on these results, Vetiver grass can be said to be effective phytostabilizer for heavy metals.

Conclusion

Spent engine oil has been documented to contain elevated levels of total hydrocarbon content (THC), and high concentration of heavy metals. These contaminants are known to pose great health hazard to man and the entire ecosystem through their contamination of of soil, air and underground water bodies thus affecting the food chain.

Vetiver grass (Vetiveria zizanioides) – a phytoremediation plant was effectively used to reduce the concentration of these contaminants from soil and plant tissues.

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