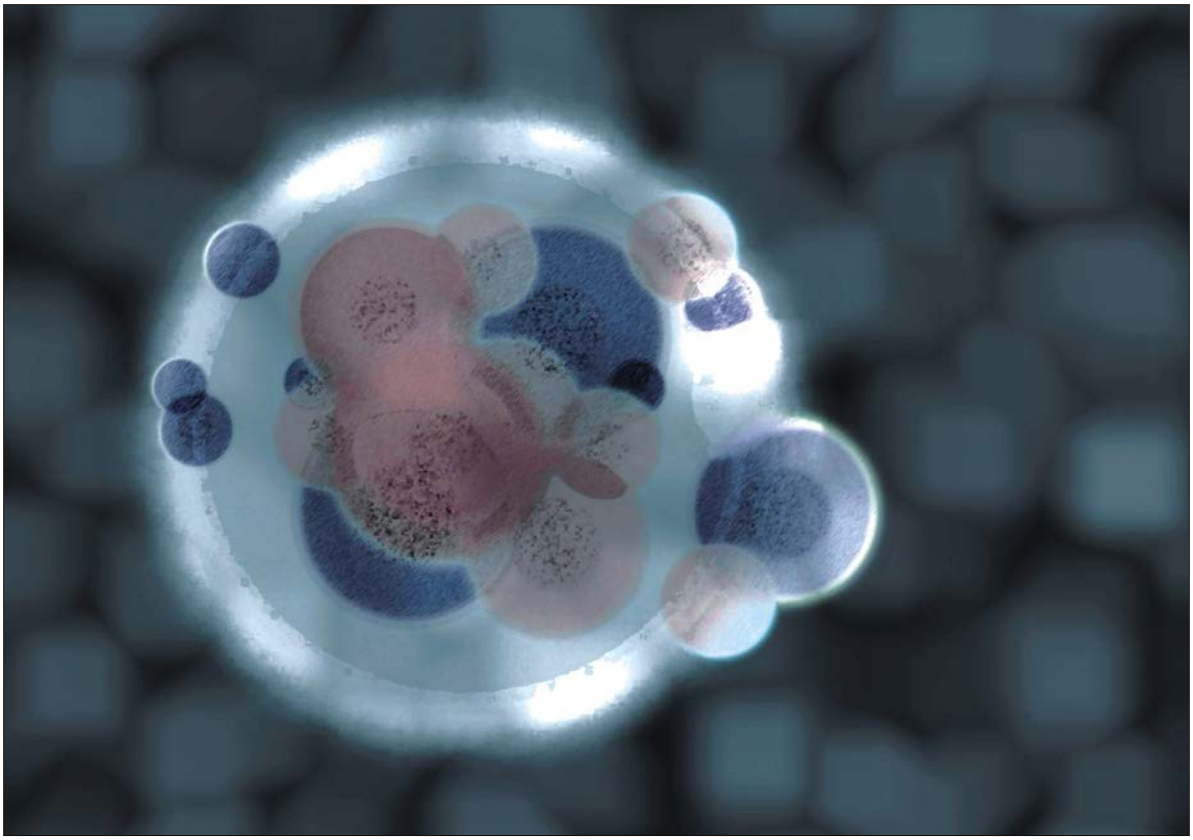

Journal of Biological Sciences

ISSN 1727-3048

science alert

ANSInet
an open access publisher
http://ansinet.com

Journal of Biological Sciences 12 (5): 280-286, 2012
ISSN 1727-3048 / DOI: 10.3923/jbs.2012.280.286
© 2012 Asian Network for Scientific Information

Weed Biodiversity Studies of a Waste Engine Oil-polluted Soil Exposed at Different Intervals of Natural Attenuation and Substrate Amendment

Beckley Ikhajiagbe and Geoffery Obinna Anoliefo
Department of Plant Biology and Biotechnology, University of Benin, Benin City, Nigeria

Abstract: The documentation of the frequency of occurrence of weed species that are prevalent in oil polluted areas is necessary to assess their capacity for tolerance and potential for phytoremediation of such polluted sites. The present study therefore investigated the impact of substrate amendment on the weed biodiversity of Waste Engine Oil (WEO)-polluted soil. Top soil (0-10 cm) was collected from an area of known soil seed bank on a farmland and measured into perforated bowls. The soil was then contaminated with WEO at 4 levels of pollution: 1.0, 2.5, 5.0 and 10.0% w/w WEO in soil. The unpolluted soil was the control. The entire set up was divided into two and then left for 5 months without mechanically disturbing the soil. The first set was amended with sawdust, whereas the second set left unamended for the remaining period of the experiment. After 10 months, there was general reduction in heavy metal composition of soil. *Euphorbia heterophylla* was the most prevalent weed, present in both amended and unamended soil treatments. Weed biodiversity studies showed that dominance indices ranged from 0.137-0.284 in the unamended soil treatments and 0.160-0.500 in the substrate-amended soil treatment levels. Substrate amendment of WEO-polluted soil therefore enhanced development of soil seed bank thereby improving weed diversity in the polluted soil probably necessitated by biodegradation of the soil contaminant.

Key words: Biodiversity, dominance indices, hydrocarbon, phytoremediation, sawdust, species richness, substrate amendment, weeds

INTRODUCTION

The preponderance of oil pollution has a major environmental concern in many countries and this has led to a concerted efforts geared towards providing various possible methods of remediation. There are several remediation technologies suited for cleanup of oil in polluted ecosystems. The most widely used procedures are the physical and chemical methods. These methods are however not favourable because of the introduction of poisonous substances into the environment (Davis and Wilson, 2005). The use of biological methods of remediation which are more environmental friendly, therefore becomes imperative. A number of factors, such as site physicochemical conditions, inherent microbial population, as well as nature and type of contaminant present, determine the suitability of a particular bioremediation technology for a specific use. Some remediation technologies involve either stimulation of resident microbial populations by nutrient modifications or by the introduction of exogenous biodegrading microbes into a contaminated site. In other to enhance the efficiency of a bioremediation technology, soil is usually substrate-amended to increase microbial activities. A soil amendment is any material that is added to a soil in order to improve its physicochemical properties (Davis and Wilson, 2005).

Other remediation technologies include phytoremediation or the use of plants to clean up the environment as well as Mycoremediation which employs fungi to biodegrade contaminants (Cunningham *et al*., 1996). Plant species required for current phytoremediation techniques are usually expected to be found within and around the zone of contamination. However, a possible drawback in the successful application of phytoremediation is the viability of plants. A clear understanding of plants' stress responses defines their potential for tolerance of a wide range of contaminants.

Indispensable tools in soil remediation are plants. They are especially important when the contaminant in its present concentration is not phytotoxic (Merckl *et al*., 2004). This is even more importance given the activities of diverse microbial populations in the rhizosphere. Frick *et al*. (1999) reported that the activities of soil microorganisms may be responsible for most of the biodegradation of petroleum hydrocarbons in vegetated soils. The occurrence of plants under specific climatic conditions (Banks *et al*., 2003) as well as tolerance of

Corresponding Author: Beckley Ikhajiagbe, Department of Plant Biology and Biotechnology, University of Benin, Benin City, Nigeria

inherent phytotoxic pollutants (Kirk *et al*., 2002) are criteria for selection of suitable plants for phytoremediation of soils contaminated with organic compounds. Other bases for plant selection include the presence of organic compounds in the plants' root exudates (Liste and Alexander, 1999) or the plants' capability to reduce the pollutant concentration in soil. Aprill and Sims (1990), Anoliefo *et al*. (2006) and Ikhajiagbe and Anoliefo (2010) have employed grasses and legumes in the phytoremediation of oil contaminated soils. The present study however employs the natural ability of the soil to remediate itself through natural attenuation and through the help of resident plant species in the soil seed bank. The researchers wish to investigate the possibility for any change in the diversity of the resident weeds grown from soil seed bank of oil polluted soil as influenced by substrate amendment as well as intervals of exposure of soil to natural attenuation.

MATERIALS AND METHODS

The present study was conducted in April 2010, spanning through a period of 15 months. Soil used was collected from an area measuring 50×50 m marked on a farmland on the main campus of the University of Benin, Benin City. Top soil (0-10 cm) was collected and air-dried to constant weight. Prior to collection of soil from the farmland, a list of all available weed species was made with a view to determining the soil seeds bank (Table 1). Thereafter, 10 kg soil each was placed into 50 large perforated 60 cm-diameter bowls with 8 perforations made with 2 mm diameter nails per bowl. WEO was obtained as pooled from an auto-mechanic workshop. The soil in each bowl was then contaminated with WEO at 5 different levels of pollution: 0, 1.0, 2.5, 5.0 and 10.0% w/w WEO according to the methods of Ikhajiagbe and Anoliefo (2010).

The entire set up was left for 5 months, without mechanically disturbing the soil. Soil was carefully irrigated twice every week with 200 mL of water. After 5 months, a list of weed species that sprouted in the bowls were identified and counted. The entire set up was then divided into two. In the first set, 3 kg of soil was removed from each bowl and replaced with 3 kg air-dried sawdust from *Brachystegia nigerica*. The bowls in the second set were left unamended for the remaining period of the experiment. The setup was left for an additional 10 months, after which a second list of emerging weed species were identified and counted. Weed biodiversity studies were therefore computed. Heavy metals as well as total hydrocarbon contents of the soil was determined at both 5 and 15 months after pollution in the amended and the unamended soils, following the methods of APHA (1985).

Table 1: Weeds identified in the area where soil was collected for the present study

Weeds	Family
Acalypha ciliata	Euphorbiaceae
Acanthospermum hispidum	Asteraceae
Ageratum conyzoides	Asteraceae
Brachiaria deflexa	Poaceae
Echinochloa stagnina	Poaceae
Eragrostis tenella	Poaceae
Erigeron floribundus	Asteraceae
Euphorbia heterophylla	Euphorbiaceae
Euphorbia hirta	Euphorbiaceae
Fleurya aestuans	Urticaceae
Gomphrena celosioides	Amaranthaceae
Ipomoea involucrata	Convolvulaceae
Panicum maximum	Poaceae
Paspalum polystachyum	Poaceae
Phyllanthus amarus	Euphorbiaceae
Platosfonca africanum	Lamiaceae
Spigelia anthelmia	Loganiaceae
Synedrella nodiflora	Asteraceae
Tridax procumbeus	Asteraceae

Computation of weed biodiversity studies: Biodiversity of weeds was computed using the formulas below. Only weeds that were >3 cm high were counted.

Given that:

S = total number of species
N = total number of individuals
ni = number of individuals in the ith species

Species richness indices:

- Margalef's index:

$$d = \frac{S-1}{Ln(N)}$$

- Menhinick's index:

$$D = \frac{S}{\sqrt{N}}$$

Diversity indices:

- Shannon's index:

$$H^i = -\sum_{i=1}^{s} pi\ In\ pi$$

Where:

$$P^i = \frac{ni}{N}$$

- Shannon-Wiener's index:

$$H^{i} = \frac{N \log N - \sum_{i=1}^{s} fi \log fi}{N}$$

This index gives the level for which a plant population consists of several species in cohabitation.

Evenness indices:

$$E = \frac{H}{H_{max}} = \frac{H}{\log S}$$

$$E^{I} = \frac{H^{I}}{LnS}$$

The index varies between 0 and 1, where E = 1 gives the situation when all species are equally abundant.

Simpson's dominance indices:

- Simpson's index:

$$C = \sum_{i=1}^{s} pi^{2}$$

$$D = \sum_{i=1}^{s} \frac{ni(ni-1)}{N(N-1)}$$

The index varies between 0 and 1 and gives the probability that two individuals drawn at random from a population belong to the same species.

RESULTS

There were 19 different species of weeds found in the areas of soil collection for the experiment (Table 1). Prominent among the plant families were Asteraceae, Poaceae and Euphorbiaceae in that order.

Heavy metal composition of soil at 5 MAP as well as at 15 MAP which is 10 months after substrate amendment, is presented on Table 2. There was general reduction in heavy metal composition of soil during the two periods. The impact of substrate amendment enhanced further utilization of the heavy metals. In the oil polluted soil treatments, Total Hydrocarbon Content (THC) of soil ranged from 3028.42-8521.12 mg L^{-1} at 5 MAP compared to 786.18-1223.23 mg L^{-1} at 15 MAP in the unamended soil and 283.5- 926.23 mg L^{-1} at 15 MAP in the substrate amended soil.

After 5 months of exposing the polluted soil (Table 3) to natural environmental conditions, the following weeds were identified on the 5 month old polluted soil; *Brachiaria deflexa, Eragrostis tenella, Euphorbia heterophylla, Panicum maximum and* a few unidentified (<5 cm tall) plants were present in the 5 month old unpolluted soil (control). These plants must have developed from the soil's seed bank. Most of these were of the family Poaceae, apart from *E. heterophylla* which is from the Euphorbiaceae family. *E. heterophylla* and a couple of unidentified plants were found at the lowest pollution level (SP_1) whereas, 4 unidentified plant species were also found in $SP_{2.5}$.

Table 4 provides computation for diversity and dominance indices for weeds at 5 months after pollution. Table 5 however describes diversity and dominance indices for weeds identified at 5 MAP. In the control (SP_0) the species richness was 1.276 as against 0.514 in SP_1. Shannon-Wiener index was 0.609 in SP_0 and 0.260 SP_1. Evenness index was given as 0.886 and 0.864 in SP_0 and SP_1 respectively. Dominance index was given as 0.274 and 0.592 in SP_0 and SP_1 respectively.

Weed distributions at 14 MAP is presented in Table 6. The following weeds were present in the *A conyzoides*, *A. hispidum*, *E. hirta* and *E. heterophylla.*

Table 2: Heavy metal composition and total hydrocarbon content of waste engine soil-polluted Soil at 5 and 15 months after pollution with or without substrate amendments, respectively

	Code	Fe	Mn	Zn	Cu	Pb	Ni	THC
5 MAP (unamended)	SP_0	768	18.5	22.8	2.3	nd	2.50	362.22
	$SP_{1.0}$	1039	30.2	36.3	3.2	0.45	2.60	3028.42
	$SP_{2.5}$	1063	35.6	47.8	3.8	0.80	3.20	4106.32
	$SP_{5.0}$	1096	36.9	56.3	3.7	1.41	4.20	7010.11
	$SP_{10.0}$	1389	38.7	68.6	4.2	2.08	4.10	8521.12
15 MAP (unamended)	SP_0	168	20.3	15.8	0.66	nd	0.08	86.53
	$SP_{1.0}$	423	25.8	15.3	1.18	0.23	0.09	786.18
	$SP_{2.5}$	698	24.2	20.2	1.30	0.49	0.12	811.23
	$SP_{5.0}$	786	34.8	30.5	1.39	0.83	0.14	987.06
	$SP_{10.0}$	1026	35.1	48.6	1.75	0.98	1.04	1223.23
15 MAP (amended)	SSP_0	206	27.9	10.3	0.82	ND	0.07	33.80
	$SSP_{1.0}$	303	32.3	20.1	1.10	0.17	0.10	283.51
	$SSP_{2.5}$	347	34.6	28.6	1.30	0.33	0.08	621.93
	$SSP_{5.0}$	618	36.3	28.5	1.37	0.62	0.13	838.11
	$SSP_{10.0}$	638	27.4	36.9	1.48	0.78	0.15	926.63

nd: Not determine

Those of 2.5% polluted soil include: *P. amarus*, *S. anthelmia*, *T. procumbens* and *P. polystachyum*.

Computation for diversity and dominance indices for weeds at 15 months after pollution, with or without substrate amendment is provided in Table 7. Species richness decreased according to intensity of pollution, from 2.552 in SP_0 to 1.365 in $SP_{2.5}$ in the soil remediated by natural attenuation (SP) at 15 MAP (Table 8).

Weeds in the soil remediated by soil amendment (SSP) had species richness ranging from 0.869-2.760. Shannon-Wiener index in the unamended soil treatment ranged from 0.569-0.993 in decreasing index according to increased pollution intensity. SSP-treatment gave Shannon-Wiener index ranges of 0.301-0.897 (Table 8). By comparing the results of corresponding levels, Shannon-Wiener indices for SP- levels were comparatively higher relative to corresponding levels of SSP, though no indices were determined for $SP_{5.0}$ and $SP_{10.0.}$ evenness indices for the unamended soil treatment levels ranged from 0.933-0.974 and 0.895-0.999 for the substrate-amended soil treatment levels.

Table 3: Weed distribution in a 5-month old naturally attenuated remediated waste engine oil-polluted soil

Weeds	SP_0	SP_1	$SP_{2.5}$	SP_5	SP_{10}	Total	Occurrence (%)
Acalypha ciliata	0	0	0	0	0	0	0
Acanthospermum hispidum	0	0	0	0	0	0	0
Ageratum conyzoides	0	0	0	0	0	0	0
Brachiaria deflexa	3	0	0	0	0	3	8.23
Echinochloa stagnina	0	0	0	0	0	0	0
Eragrostis tenella	2	0	0	0	0	2	5.88
Erigeron floribundus	0	0	0	0	0	0	0
Euphorbia heterophylla	2	2	0	0	0	4	11.76
Euphorbia hirta	0	0	0	0	0	0	0
Fleurya aestuans	0	0	0	0	0	0	0
Gomphrena celosioides	0	0	0	0	0	0	0
Ipomoea involucrata	0	0	0	0	0	0	0
Panicum maximum	8	0	0	0	0	8	23.53
Paspalum polystachyum	0	0	0	0	0	0	0
Phyllanthus amarus	0	0	0	0	0	0	0
Platosfonca africanum	0	0	0	0	0	0	0
Spigelia anthelmia	0	0	0	0	0	0	0
Synedrella nodiflora	0	0	0	0	0	0	0
Tridax procumbeus	0	0	0	0	0	0	0
Unidentified plants (<5 cm tall)	8	5	4	0	0	17	50.00
Total	23	7	4	0	0	34	100.00

Table 4: Computation for diversity and dominance indices for weeds at 5 months after pollution

	fi	fi log fi	pi = ni/N	pi ln pi	pi^2	ni(ni-1)/N(N-1)
SP_0	3	1.431	0.130	-0.265	0.0170	0.0119
	2	0.602	0.087	-0.212	0.0076	0.0040
	2	0.602	0.087	-0.212	0.0076	0.0040
	8	7.225	0.348	-0.367	0.1210	0.1107
	8	7.225	0.348	-0.375	0.1210	0.1107
Σ	23	17.085	1.000	-1.423	0.2742	0.2412
$SP_{1.0}$	2	0.602	0.286	-0.358	0.0816	0.0475
	5	3.495	0.714	-0.241	0.5102	0.4768
Σ	7	4.097	1.000	-0.599	0.5918	0.5238

fi: No. of each weed species present per treatment, N: Total No. of individuals, ni = No. of individuals in the ith species, pi = ni/N

Table 5: Diversity and dominance indices for weeds present in the naturally attenuated WEO-polluted soil at 5 months after pollution

Parameters	SP_0	$SP_{1.0}$	$SP_{2.5}$	SP_5	$SP_{10.0}$
Species richness (d)	1.276	0.514	NA	NA	NA
Species richness (D)	1.043	0.756	NA	NA	NA
Shannon-Wiener index (H)	0.609	0.260	NA	NA	NA
Shannon index (H^I)	1.423	0.599	NA	NA	NA
Evenness index (E)	0.886	0.864	NA	NA	NA
Evenness index (E^I)	0.884	0.864	NA	NA	NA
Dominance index(C)	0.274	0.592	NA	NA	NA
Simpson's index (D)	0.241	0.524	NA	NA	NA
Reciprocal (D^I)	4.149	1.908	NA	NA	NA

NA: Not available

Table 6: Weeds distribution of waste engine oil-polluted soil at 15 months after pollution, with or without substrate amendment

	SP_0	SP_1	$SP_{2.5}$	SP_5	SP_{10}	SSP_0	SSP_1	$SSP_{2.5}$	SSP_5	SSP_{10}	Total	Occurrence (%)
Acalypha ciliata	2	2	0	0	0	0	0	0	0	0	4	2.87
Acanthospermum hispidum	0	0	0	0	0	2	2	0	2	1	7	5.03
Ageratum conyzoides	0	2	0	1	0	0	0	0	0	0	3	2.16
Brachiaria deflexa	3	0	0	0	0	1	0	0	0	0	4	2.87
Echinochloa stagnina	3	0	0	0	0	0	0	0	0	0	3	2.16
Eragrostis tenella	2	0	0	0	0	1	2	0	0	0	5	3.58
Erigeron floribundus	0	0	0	0	0	0	1	0	0	0	1	0.72
Euphorbia heterophylla	2	5	3	0	0	4	2	4	0	1	21	15.11
Euphorbia hirta	0	2	0	0	0	2	0	0	1	0	5	3.59
Fleurya aestuans	2	0	0	0	0	0	0	0	0	0	2	1.43
Gomphrena celosioides	0	0	0	0	0	1	0	0	0	0	1	0.72
Ipomoea involucrata	0	0	0	0	0	0	0	0	0	0	0	0.00
Panicum maximum	9	2	0	0	0	0	0	0	0	0	11	7.91
Paspalum polystachyum	0	0	0	0	0	0	0	1	0	0	1	0.72
Phyllanthus amarus	2	3	1	0	0	3	3	0	0	0	12	8.63
Platosfonca africanum	0	0	0	0	0	0	0	0	0	0	0	0.00
Spigelia anthelmia	2	0	1	0	0	0	0	0	0	0	3	2.16
Synedrella nodiflora	2	0	0	0	0	2	0	0	0	0	4	2.87
Tridax procumbeus	4	4	2	0	0	2	0	0	0	0	12	8.63
Unidentified plants (<5 cm tall)	5	4	3	5	0	8	8	5	3	0	41	29.48
Total	38	24	9	6	0	26	18	10	6	2	139	100.00

Table 7: Computation for diversity and dominance indices for weeds at 15 months after pollution, with or without substrate amendment

	fi	fi log fi	pi = ni/N	pi ln pi	pi^2	ni(ni-1)/N(N-1)
SP_0	3	1.431	0.083	-0.207	0.0069	0.0053
	3	1.431	0.083	-0.207	0.0069	0.0053
	2	0.602	0.059	-0.167	0.0035	0.0018
	2	0.602	0.059	-0.167	0.0035	0.0018
	2	0.602	0.059	-0.167	0.0035	0.0018
	9	8.588	0.267	-0.353	0.0701	0.0642
	2	0.602	0.059	-0.167	0.0035	0.0018
	2	0.602	0.059	-0.167	0.0035	0.0018
	4	2.408	0.118	-0.252	0.0138	0.0107
	5	3.495	0.147	-0.282	0.0216	0.0178
Σ	34	20.363	1.000	-2.136	0.1368	0.1123
$SP_{1.0}$	5	3.495	0.278	-0.356	0.0772	0.0654
	2	0.602	0.111	-0.244	0.0123	0.0065
	3	1.431	0.167	-0.299	0.0278	0.0196
	4	2.408	0.222	-0.334	0.0494	0.0392
	4	2.408	0.222	-0.334	0.0494	0.0392
Σ	9	3.464	1.000	-1.567	0.2161	0.1699
$SP_{2.5}$	3	1.431	0.333	-0.366	0.1111	0.0833
	1	0.000	0.111	-0.244	0.0123	0.0000
	2	0.602	0.222	-0.334	0.0494	0.0278
	3	1.431	0.333	-0.366	0.1111	0.0833
Σ	9	3.464	1.00	-1.310	0.2839	0.1944
SSP_0	2	0.602	0.077	-0.197	0.0059	0.0031
	1	0.000	0.038	-0.124	0.0015	0.0000
	1	0.000	0.038	-0.124	0.0015	0.0000
	4	2.408	0.154	-0.288	0.0237	0.0185
	2	0.602	0.077	-0.125	0.0015	0.0000
	1	0.000	0.038	-0.124	0.0015	0.0000
	3	1.431	0.115	-0.249	0.0133	0.0092
	2	0.602	0.077	-0.197	0.0059	0.0031
	2	0.602	0.077	-0.197	0.0059	0.0031
	8	7.225	0.308	-0.363	0.0947	0.0862
Σ	26	13.472	1.000	-2.060	0.1598	0.1263
$SSP_{1.0}$	2	0.602	0.111	-0.244	0.0123	0.0065
	2	0.602	0.111	-0.244	0.0123	0.0065
	1	0.000	0.056	-0.161	0.0031	0.0000
	2	0.602	0.111	-0.244	0.0123	0.0065
	3	1.431	0.167	-0.29	0.0278	0.0196
	8	7.225	0.444	-0.360	0.1975	0.1830
Σ	18	10.460	1.000	-1.552	0.2653	0.2221
$SSP_{2.5}$	4	2.408	0.400	-0.367	0.1600	0.1333
	1	0.000	0.100	-0.230	0.0100	0.0000
	5	3.495	0.500	-0.347	0.2500	0.2222
Σ	10	5.903	1.000	-0.944	0.4200	0.3555
$SSP_{5.0}$	2	0.602	0.333	-0.366	0.111	0.0667
	1	0.000	0.167	-0.299	0.028	0.0000
	3	1.431	0.500	-0.347	0.250	0.2000
Σ	6	2.033	1.000	-1.012	0.389	0.2667
$SSP_{10.0}$	1	0.000	0.500	-0.347	0.250	0.0000
	1	0.000	0.500	-0.347	0.250	0.0000
Σ	2	0.000	1.000	-0.694	0.500	0.0000

SP: Unamended, SSP: Substrate-amended, fi: No. of each weed species present per treatment, N: Total number of individuals, ni: No. of individuals in the ith species, pi: ni/N

Comparatively, the unamended soil treatment levels gave higher evenness indices compared to the amended ones. Generally, the order of decreasing E was as follows; $SSP_{10} > SP_{1.0} > SP_{2.5} > SP_0 > SSP_{5.0} > SSP_0$ ...

Dominance indices ranged from 0.137-0.284 in the unamended soil treatments and 0.160-0.500 in the substrate-amended soil treatment levels. Generally, dominance indices in each method of remediation increased with increasing levels of pollution. Orders of decreasing dominance indices include $SSP_{10.0} > SSP_{2.5} > SSP_{5.0} >$... $> SP_0$. dominance indices were not determined for $SP_{5.0}$ and $SP_{10.0}$. Simpson's index was highest in $SSP_{2.5}$ (0.356) and lowest in SP_0 (0.112).

DISCUSSION

The presence of heavy metals in soil raises a lot of environmental concerns. This is particularly important in their relationships with plant growth. They render the land unsuitable for plant growth thereby destroying the biodiversity. The availability of metals and metalloids in soil to plants, to a large extent, depends on the selective absorption from soil solution by plant roots. These metals and metalloids may be bound to exterior exchange sites on the root and not actually taken up. Efroymson *et al.* (1997) however observes that these metals may enter the root passively in organic or inorganic complexes or actively by metabolically controlled membrane transport systems. Although several regulatory steps have been implemented to reduce the release of pollutants in the soil, they are not sufficient for checking the contamination. However, plant resistance to these pollutants has been demonstrated in previous studies by Wong and Chu (1985) in *Cynodon dactylon,* Anoliefo and Edegbai (2000) in *Solanum melongena* and *S. incanum,* Dede *et al.* (2003) in *Celosia argentea and* Ikhajiagbe and Anoliefo (2010, 2011) in *Vigna unguiculata.* Because of plants differential response to pollutants, such unhealthy environmental practices as improper WEO disposal would affect the distribution of plants species over time and space in affected areas.

In the present study, although reduction in metal concentration in soil occurred even before the emergence of weeds on soil surface, remediation might have taken place by a number of factors other than by green plants. One of such is the possibility for dissolution of water soluble heavy metal compounds by soil water and consequent translocation into ground water. Another way is by chelation. In spite of this, Phytoremediation however lends greater benefit for heavy metal remediation. Identification of plants species that are prevalent in pollutant-contaminated sites is prerequisite to finding out their inherent capacity for tolerance and potential for phytoremediation. At 5 MAP, *Brachiaria deflexa, Eragrostis tenella, Euphorbia heterophylla* and unidentified weeds (<5 cm tall) were present in the control (SP_0) and *Euphorbia heterophylla* in SP_1. At 15 MAP, *Euphorbia heterophylla* was the most dominant weed

Table 8: Diversity and dominance indices for weeds in waste engine oil-polluted soil at 15 months after pollution, with or without substrate amendment

Treatments	Species richness (d)	Species richness (D)	Shannon-Wiener index (H)	Shannon index (H^1)	Evenness index (E)	Evenness index (E^I)	Dominance index (C)	Simpson's index (D)	Reciprocal (D^I)
SP_0	2.552	1.715	0.933	2.136	0.933	0.928	0.137	0.112	8.929
$SP_{1.0}$	1.384	1.179	0.681	1.567	0.974	0.974	0.216	0.170	5.882
$SP_{2.5}$	1.365	1.333	0.569	1.310	0.945	0.945	0.284	0.194	5.155
$SP_{5.0}$	NA	NA	NA	NA	NA	NA	NA	NA	NA
$SP_{10.0}$	NA	NA	NA	NA	NA	NA	NA	NA	NA
SSP_0	2.760	1.961	0.897	2.060	0.895	0.895	0.160	0.126	7.937
$SSP_{1.0}$	1.730	1.414	0.674	1.552	0.866	0.866	0.265	0.222	4.505
$SSP_{2.5}$	0.869	0.949	0.410	0.944	0.859	0.859	0.420	0.356	2.809
$SSP_{5.0}$	1.116	1.225	0.439	1.012	0.920	0.921	0.389	0.267	3.750
$SSP_{10.0}$	1.443	1.414	0.301	0.964	0.999	1.000	0.500	0.000	8.000

NA: Not available, SP: Unamended, SSP: Substrate-amended

(present in both SP and SSP), with 15.11% occurrence, followed by *Phyllanthus amarus* and *Tridax procumbens* (8.63%) *and Panicum maximum* (7.91%).Comparing species richness and diversity of weeds present in the soil treatments at 15 MAP, species richness was better in the controls. Plant diversity was higher in the unamended soil than in the substrate-amended soil treatments. However, species dominance was higher in unamended soil treatments. There are several plant characteristics that exclude species for possible use in phytoremediation which need consideration. For example, *T. procumbens* is an undesirable invasive weed that can replace natural pastures, a characteristic that could cause conflicts with farmers in surrounding of remediation site and additional costs for weed control (Merckl *et al*., 2004).

Anoliefo *et al*. (2006) identified a number a plants in an oil-polluted auto-mechanic workshop, suggesting therefore that these weeds could have a tolerance for oil. These weeds included *Tridax procumbens*, *Acanthospermum hispidum*, *Euphorbia heterophylla, Eragrostis tenella*, *Panicum maximum* and *Fleurya aestuans*. The capability for *Talinum triangulare, Celosia trigyna, Corchorus olitorius, Vernonia amygdalina* and *Telfairia occidentalis* as well as grasses like *Eleusine indica, Cynodon dactylon, Panicum maximum, Euphorbia hirta, Chromolaena odorata* for recovery of heavy metals from soil has also been reported (Wong and Chu, 1985; Wong and Lau, 1985; Anoliefo and Vwioko, 2001). A number of these weeds have been identified in the present study (Table 3).

Current rate of urban development has informed the decision for a number of contaminated sites being converted to parks and other low-intensity public uses. This usually would include landscaping the sites with grasses or other weeds of aesthetic value. These sites, particularly with their greater flexibility in the timing and design of cleanup, frequently offer significant ecological opportunities. Business corporations traditionally landscape their premises with grasses for aesthetic reasons and storm run-off control. These functions may be combined with phytoremediation to offer significant opportunities. When properly designed and located, such landscaping could also provide long-term management and enhanced ecological habitats. A site owner may be willing to significantly expand the land committed to phytoremediative landscaping if that commitment would reduce overall cleanup costs and allow quicker site redevelopment. A phased approach, with intensive short-term treatment by one plant species followed by permanent plantings with more beneficial vegetation, may maximize ecosystem benefits.

CONCLUSION

The present study shows that amending the soil offers greater opportunities for increased weed diversity, thereby enhancing phytoremediation. A soil amendment improves the soil's physical properties, such as water retention, permeability, water infiltration, drainage, aeration and structure. It also makes for better microbial action on the oil pollutant. Specifically, however, to assess the appropriateness of any phytoremediation technology, site-specific and contaminant-specific field data must be obtained in other to show the rate and extent of degradation or accumulation. Currently there is no industry or research consensus on which parameters are crucial to measure for most phytoremediation projects. Specific data are therefore needed on more plants, including plant presence and tolerance mechanisms in pollutant-contaminated soils, nature and mode of action of contaminants and climate conditions to enhance the current knowledge base. This must also include the standardization of monitoring systems.

ACKNOWLEDGMENT

The authors are thankful to Raw Materials Research and Development Council, Abuja, for the research grant.

REFERENCES

APHA, 1985. Standard Method for the Examination of Water and Waste Water. American Public Health Association, Washington DC., USA., Pages: 256.

Anoliefo, G.O. and B.O. Edegbai, 2000. Effect of spent engine oil as a soil contaminant on the growth of two egg plant species, *Solanummelongena* (L.) and *S. incanum* (L.). J. Agric. For. Fish., 1: 21-25.

Anoliefo, G.O. and D.E. Vwioko, 2001. Tolerance of *Chromolaena odorata* (L) K and R. grown in soil-contaminated with spent lubricating oil. J. Trop. Biosci., 1: 20-24.

Anoliefo, G.O., B. Ikhajiagbe, B.O. Okonokhua and F.V. Diafe, 2006. Eco-taxonomic distribution of plant species around auto mechanic workshops in Asaba and Benin City: Identification of oil tolerant species. African J. Biotechnol., 5: 1757-1762.

Aprill, W. and R.C. Sims, 1990. Evaluation of the use of prairie grasses for stimulating polycyclic aromatic hydrocarbon treatment in soil. Chemosphere, 20: 253-265.

Banks, M.K., P. Schwab, B. Liu, P.A. Kulakow, J.S. Smith and R. Kim, 2003. The effect of plants on the degradation and toxicity of petroleum contaminants in soil: A field assessment. Adv. Biochem. Eng. Biotechnol., 78: 75-96.

Cunningham, S.D., T.A. Anderson, A.P. Schwab and F.C. Hsu, 1996. Phytoremediation of soil contaminated with organic pollutants. Adv. Agron., 56: 55-114.

Davis, J.G. and C.R. Wilson, 2005. Choosing a soil amendment: Fact sheet No. 7.235. Colorado State University. http: //www.ext.colostate.edu/pubs/garden/07235.html

Dede, E.B., N.M. Igboh and O.E. Ayalogu, 2003. Ecotoxicological effect of crude oil (Bonny Light), kerosene and gasoline on *Celosia argentia* plant. J. Nigerian Environ. Soc., 1: 131-136.

Efroymson, R.A., M.E. Will, G.W. Suter II and A.C. Wooten, 1997. Toxicological Benchmarks for screening contaminants of potential concern for effects on terrestrial plants: 1997 revision. ES/ER/TM-85/R3. US Department of Energy, Office of Environmental Management, Pages: 1-123.

Frick, C.M., R.E. Farrell and J.J. Germida, 1999. Assessment of phytoremediation as an *in situ* technique for cleaning oil-contaminated sites. PTAC Petroleum Technology Alliance, Canada, Calgary, pp: 88

Ikhajiagbe, B. and G.O. Anoliefo, 2010. Impact of soil amendment on phytotoxicity of a 5-month old waste engine oil polluted soil. J. Ecol. Natural Environ., 2: 112-1122.

Ikhajiagbe, B. and G.O. Anoliefo, 2011. Natural attenuation of a 14-month-old waste engine oil polluted soil. J. Soil Sci. Environ. Manage., 2: 184-192.

Kirk, J.L., J.N. Klironomos, H. Lee and J.T. Trevors, 2002. Phytotoxicity assay to assess plant species for phytoremediation of petroleum-contaminated soil. Bioremed. J., 6: 57-63.

Liste, H.H. and M. Alexander, 1999. Rapid screening of plants promoting phenanthrene degradation. J. Environ. Quality, 28: 1376-1377.

Merckl, N., R. Schutze-Kraft and C. Infante, 2004. Phytoremediation in the tropics: The effect of crude oil on the growth of tropical plants. Bioremed. J., 8: 177-184.

Wong, M.H. and L.M. Chu, 1985. Yield and metal uptake of *Cynodon dactylon* (*Bermuda grass*) grown in refuse-compost-amended soil. Agric. Ecosyst. Environ., 14: 41-52.

Wong, M.H. and W.M. Lau, 1985. Root growth of *Cynodon* and *Eleusine indica* collected from motorways at different concentrations of lead. Environ. Res., 36: 257-267.