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Yield of maize (*Manoma spp*) affected by automobile oil waste and compost manure

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The study is aimed at evaluating the effects of compost manure on the remediation of automobile oil waste polluted soils, and on the yield parameters (plant height, leave surface and dry matter weight) of maize (*Manoma spp*). Analyses of soil samples of contaminated and uncontaminated sites collected with core samplers at 10 cm depth and auger samplers at two depths (surface, 0 – 20 cm; subsurface, 20 – 40 cm) were examined for chemical and physical properties, including poly aromatic hydrocarbons. Polluted soils were biotreated for testing maize in a greenhouse. Soil physical and chemical properties decreased with depth and were significantly (P<0.05) affected by contamination. Decreases in soil poly aromatic carbon from original concentration were observed. Phyto-assessment showed that maize seedlings bio-accumulated heavy metals in polluted soils, which made their survival rate marginal relative to those grown in uncontaminated soils. Soil amendment with compost manure significantly (P<0.05) improved soil properties and maize yield variables. Ecological risk factor (HQ>1) of heavy metals (for example; Zn, Cu, Mn) was high for maize cultivation. Paradigm approach emphasizing sustainable biological soil systems management is desired. Particularly, bioremediation of oil polluted soils using organic materials, and siting of mechanic villages several kilometers away from major land uses (residential houses, farm lands, and usable water bodies) are important for protecting the soil resources for agricultural purposes, and to ensuring environmental sanity and sustainability.

Key words: Automobile oil wastes, phytotoxicity, soil amendment, poly aromatic carbons.

INTRODUCTION

Petroleum hydrocarbon, its refined products and byproducts plays important role in the development of the economy of nations, including Nigeria. Refined products such as petrol, diesel, kerosene, among others and byproducts like oil, waxes drives the economy as it creates livelihoods and development.

However, in routine maintenance of vehicles, mechanic operators would always discharge petroleum and its derivatives (example, spent engine oil) leaving behind serious environmental concerns. Arising from indiscriminate location of mechanic sites and the effects of soil and environmental contamination by the petroleum byproducts in most cities of Enugu State, Nigeria. The government decided to concentrate these motor vehicle

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servicing centers within a location and designate it as "mechanic village".

A mechanic village is an area of open land allocated to automobile workers in the vicinity of urban/peri-urban areas. In these places, they specialize in repairs and servicing of vehicles. They also serve as large scale skill acquisition centers for auto mechanics, auto electricians, spray painters, panel beaters, welders, spare parts fabricating and machine operators, spare parts dealers among others.

Even though heavy metals are naturally present in soils, but the environment of auto workshops is increasingly exposed to changes due to anthropogenic sources that could create vast amount of various wastes and pollutants, and adequate attention has not been given to its disposal. These pollutants could be drastic and as such affect ecosystem substantially. It also can affect the trophic chain, plants, animals, and man and can remain in the soil for a long time (Osuji and Nwoye, 2007).

The disposal of spent engine oil (SEO, a brown-to-black liquid) into gutters, water drains, open vacant plots and farm soils is a common practice especially by motor mechanics. This waste engine oil is usually obtained after servicing and subsequently draining from automobile and generator engines (Anoliefo and Edegbai, 2000).

Relatively large amounts of hydrocarbons in the used oil, including the highly toxic polycyclic aromatic hydrocarbons have been reported (Wang et al., 2000). Shayler et al. (2009) report showed that engine oil may contain chromium, lead, molybdenum, or nickel from engine wear, while used batteries release lead or mercury. These heavy metals may be retained in soils in the form of oxides, hydroxides, carbonates, exchangeable cations, and/or bound to organic matter in the soil.

Spent engine oil hydrocarbons, when present in the soil, creates an unsatisfactory condition for life in the soil, thus causing poor soil aeration, immobilization of soil nutrients, and lowering of soil pH (Atuanya, 1987), unsatisfactory for plant growth due to the reduction in the level of available plant nutrient (soil bio-physical and chemical properties) or a rise in toxic levels of certain elements such as iron and zinc (Udo and Fayemi, 1975).

Due to inadequate waste disposal infrastructure, proper management of these wastes has become a cause for concern. The processes that lead to the removal of these heavy metals and hydrocarbon pollutants from the environments involve physical, chemical and biological alternatives. Madsen (1991) has shown that biological approach is most preferred to physical and chemical alternatives because they reintroduce the contaminants into the environment.

Bioremediation is the spontaneous process in which biology, especially microbial catalysis, acts on pollutant compounds, thereby eliminating environmental contamination (Madsen, 1991). Maize is a staple food crop that provides protein and calories for human need. It can easily adapt in famers' cropping system with low input technology of production.

The effects of remediation strategies on the phytotoxicity of waste crude oil-polluted soil on maize yield parameters constitute an important thrust of this study. Studies, elsewhere, have obtained stabilization of waste through biotreatment (Diaz et al., 1996) but Enugu state has received less attention in these areas of assessment. Also, with paucity of data upon which to determine soil health for a specific land use type, especially in study locations, many fundamental questions concerning the mechanic effluent fluxes and distribution of soil nutrients in relation to maize crop production remain unanswered.

The study aims to provide information on the effects of compost manure on the remediation of automobile oil waste polluted soils, and on the yield parameters (plant height, leave surface and dry matter weight) of maize (*Manoma* spp).

MATERIALS AND METHODS

Description of study area

The study was conducted in the screen house of the University of Nigeria, Nsukka using oil waste contaminated and uncontaminated soils collected from automobile workshops located in Udi, Nsukka, and Udenu local government areas (LGAs) in Enugu State, Nigeria.

Udi LGA covers an area of 897 km^2 and lays 6°19'N and 7°26'E with a population of about 234, 002. Nsukka LGA lies by latitude 6°51'24" and longitude 7°23'45"E with land area of 45.38 km^2. Udenu LGA lies between coordinates 6°55'N and 7°31'E with a total land area of 897 km^2 and a population of about 178, 466 (http://www.nipost.gov.ng/postcode.aspx).

The vegetation of Enugu state is of the semitropical rainforest type and complemented by typical grassy vegetation. The soils are ferrallitic (also called red earth or acid sands) ultisol. The state is predominantly rural agrarians, with a substantial proportion of its working population engaged in farming.

Field work

Soils contaminated with automobile waste oil were collected from Ngwo, Umuakashi and Obollo-Afor mechanic villages situated, respectively, in Udi, Nsukka and Udenu LGAs within South eastern Nigeria. The soils were sampled at depth of 0-20 and 20-40 cm with soil auger within an area measuring 50 × 50 m using the random sampling technique. Uncontaminated soils were collected for standardization. Core ring (volume - 96.6 cm^3) samples were taken at soil depth of 0-10 cm. All soil samples were used for soil property determinations and maize planting in the screen house.

Screenhouse studies

The soils collected from the fields of each location weighing 5 kg were air dried. Thereafter 2.5 kg of each site soil was measured into poly bags. Each poly bag was amended with 1.5 kg of air-dried compost manure (CM) except the control. Treatment details were as follows:

i) Three bags each of contaminated and uncontaminated soil samples with 0 kg CM

ii) Three bags each of contaminated and uncontaminated soil samples with + 1.5 kg CM.

The compost manure was thoroughly mixed into the soils and 0.5 kg of river sand added. The entire set up was left to decompose for three months period. 50 ml of water was applied at intervals.

Phyto assessment

After the 3 months period, soil in each bag was turned and properly mixed and watered (200 ml) prior to maize sowing. *Manoma spp* of improved maize seeds were sown into each bag at the rate of 3 seeds to a depth of 3 cm, and thinned down to 2 seedlings per bag after seedling had attained 2-leaf stage. The soil bags were constantly weeded. Measurements were made on the growth and yield parameters (height, leaf surface and dry matter yield) of the improved maize.

Laboratory analysis

Bulk density (Bd) and saturated hydraulic conductivity (Ksat) were determined using Grossman and Keinch (2002) method, while total porosity was calculated using Bd data. The auger soil samples were air-dried in the laboratory ground and passed through a 2 mm sieve. Sieved samples < 2 mm soil fraction was bagged for routine analysis.

The fraction of sand, silt, and clay was determined using hydrometer method (Gee and Or, 2002) with NaOH as dispersant. Soil pH was determined by McLean (1982) method. Total nitrogen was determined using micro- Kjeldahl (Bremner and Mulvaney, 1982) method. Soil organic carbon was Soil measured by combustion at 840°C (wet-oxidation method)(Wang and Anderson, 1998).

Soil organic matter was obtained by multiplying the value for organic carbon by the "Van Bermenalen factor" of 1.724. For exchangeable bases, Ca^{2+} and Mg^{2+} was obtained by ammonium acetate (NH4 OAC) method, and Na^+ and K^+ by Flame photometer for cation exchange capacity (CEC) was obtained using Blakemore et al. (1987) method. Available phosphorus was obtained using Bray 11 bicarbonate extraction method as described by Olsen and Sommers (1982). Trace elements and lead were determined using Atomic Absorption Spectrophotomettry (AAS). Poly aromatic hydrocarbons were determined.

Computation

Hazard quotient (HQ): HQ expresses the possibility of the contaminant being an ecological risk or a contaminant of potential ecological concern. The hazard quotient (HQ) was calculated as follows:

HQ = Measured concentration/Toxicity reference value (Lindsay and Novell, 1977)

When HQ > 1: Harmful effects are likely due to contaminant in question

When HQ = 1: Contaminant alone is not likely to cause ecological risk

When HQ < 1: Harmful effects are not likely

Bioaccumulation quotient (BQ): This expresses the possibility of contaminant being significantly accumulated in plant parts, thereby posing health threats. It was expressed by the following equation:

BQ = Concentration of accumulated pollutant in the accumulant / Concentration of accumulated pollutant.

Plant height, leaf surface and dry matter weight of maize plant were measured.

Data analysis

Data on maize yield variables, soil physical and chemical properties were subjected to analysis of variance (ANOVA) using GenStat Discovery Edition 3, while the significant variations in the means were determined using Fischer's LSD (least significance difference) at 5% probability.

RESULTS AND DISCUSSION

Effects of contamination, location and soil depth on soil physicochemical properties

Some physical properties of the soil used for the study are presented in Table 1. Soil texture varied from sandy loam to loamy sand attributable to nature of parent materials and high rainfall that could favor washing away and leaching of silt-sized and clay-sized fractions. Similar observation has been made (Ekundayo and Obuekwe, 1997).

Soil bulk density (Bd) significantly ($P<0.05$) increased by 25%, while Ksat decreased (81%) due to effects of pollution. Increased Bd suggests compaction due to rainfall that clog the pore spaces in soils, while surface sealing arising from the presence of oil deposit on the top soil layer (hydrophobic layer) prevents water penetration. Lower Bd obtained in the uncontaminated soils is a positive productivity indicator as it helps in easing root penetration, and encourages downward movement of water through old root channels (Mbah et al., 2009). Low soil Bd and higher saturated hydraulic conductivity (Ks) as obtained in control soil could lower run-off and erosion, while increasing aeration and internal drainage (Remon et al., 2005).

Total porosity (TP) decreased by 3.1% in contaminated and increased (86.9%) in unpolluted soil. Value of available water capacity (AWC) was lower (30.6%) at Nsukka compared to Ngwo (37.7%) and Obollo Afor (43.8%) (Table 1). High AWC may be associated to the high value (18.1 %) of clay, which has the ability to retain water.

Soil pH reduced from 6.8 to 6.4 (5% reduction) in contaminated soil due to significant ($P < 0.05$) increase in Al^{3+} content. However, petroleum hydro-carbon mediated decrease in soil pH has been attributed to the production of organic acids by microbial metabolism (Osuji and Nwoye, 2007; Remon et al., 2005) as well as degradation of the hydrocarbons, which may have resulted in the release of acidic intermediates and final products that probably lowered pH of the mixture (Wang et al., 1999). Low pH have been associated to loss of exchangeable bases (Ca^{2+}, Mg^{2+}, K^+, Na^+) due to displacement reactions in the soil colloidal complex and excessive rainfall that could lead to eluviations and leaching loses (Ngobiri et

Table 1. Effects of contamination, location and soil depth on soil physical properties.

Soil sample	Texture	Clay%	Silt %	Fine sand %	Coarse sand %	Total sand %	TP%	KsCm/s	BDg/cm^3
Contamination									
Contaminated	LS	14.8	12.22	24.6	48.5	73.1	36	1.13	1.70
Uncontaminated	LS	8.7	8.83	24.8	46.7	71.5	49	5.81	1.36
LSD (p <0.05)		4.80	2.38	Ns	5.49	4.11		2.61	0.04
Location									
Nsukka	LS	10.8	6.63	23.01	59.8	82.8	43	4.45	1.50
Ngwo (9th mile)	LS	9.3	7.22	26.22	57.2	83.5	34	3.60	1.75
Obollo-afor	SL	18.1	10.22	24.96	46.7	71.7	49	2.36	1.35
LSD (P<0.05)		5.88	2.92	1.98	6.72	7.48	Ns	Ns	Ns
Soil Depth									
0-20cm	LS	11.8	6.55	27.02	54.6	81.6	nd	Nd	nd
20-40cm	LS	13.7	9.49	22.44	54.6	77.0	nd	Nd	nd
LSD (P <0.05)		Ns	2.38	1.61	ns	Ns	nd	Nd	nd

Ks, soil saturated hydraulic conductivity; BD, soil bulk density; TP, total porosity; AWC, available water capacity; LSD, least significant difference; NS, not significant; nd, not determined; Ls, loamy sand; SL, sandy loam.

al., 2007).

The results show organic carbon (OC) of contaminated soil to have increased significantly (P<0.05) by 196.3% relative to control (Table 2). This increase could be linked to high content of carbon in the oil, most of which are of fossil origins. Low contents of N, P and K in polluted soil (Table 2) confirms earlier report (Lehtomaker and Niemela, 1975) that showed low value of N, P and K reserve in petroleum hydrocarbon contaminated soil.

Exchangeable Ca, Mg and K decreased by 34.3%, 27 and 8.3%, respectively, in contaminated soil, suggesting displacement reaction in the cation exchange site by the active exchangeable Al^{3+}.

This result is contrary to earlier findings by Amadi et al. (1993) who reported increases in the cations of polluted soils. Lack of significance of CEC, Ca^{2+}, K^+, CEC, and H^+ insinuates that contamination had no effect on these parameters.

Available P significantly (P<0.05) reduced by 40% in polluted soil (Table 2) and could be attributed to high hydrocarbon content in the automobile waste oil, which may have fixed available P, hence less availability (Ekundayo and Obuekwe, 1997).

Effects on trace elements and lead contents

The results (Table 3) show that there was heavy metal presence in contaminated soil relative to uncontaminated soil. The heavy metal composition of soil for Iron (Fe) ranged from 2.05 to 3.92 mg kg^{-1}, Mn (2.91-3.20 mg kg^{-1}), Zn (2.97-3.92 mg kg^{-1}), Pb (0.10-0.04 mg kg^{-1}), Cu (2.94-2.29 mg kg^{-1}), while Boron concentration was lower (2.63 mg kg^{-1}) in contaminated when compared with uncontaminated (3.02) soil. Both increases and/or decreases in contamination and at soil depth levels were significant (P<0.05). The increase in micro-nutrient or trace elements under contaminated soil is expected as oil pollution on soils makes some nutrients that are toxic to plants like Mn more available (Adeniyi and Afolabi, 2002; Mbah et al., 2009).

Interaction of contamination by location and by soil depth was significant (P<0.05) for all heavy metals except Zn. Increased concentration of heavy metals and especially lead (Pb) could be due to large admixture of the crude oil effluents with transmission and brake fluid and paint, gasoline, diesel, and other petrochemicals (Osu and Okereke, 2010).

Effect of oil contamination on soil poly aromatic hydrocarbon (PAH) contents

Decreases in soil poly aromatic hydrocarbon from original concentration were observed (Table 4). Acenaphthene decreased from 0.2461 to 0.2117 mg/l. The total PAH reduced from 5.8029 to 1.3425 mg/l. PAH reductions may have resulted from evaporation and microbial degradation in a dissolved state (Wang et al., 2000; Kastner and Mahro, 1996; Lehtomaker and Niemela, 1975).

Impact of remediation on maize yield factors (phyto assessment)

The hazard quotient of Zn (4.9), Cu (14.9) and Mn (3.2) was greater than unity (1), suggesting possibility of harmful effects (ecological risks) of trace elements and

Table 2. Effects of contamination, location and soil depth on soil chemical properties.

Soil sample	pH H_2O	pH Kcl	OC%	OM%	Total N%	Ca^{2+} (Cmol/kg)	Mg^{2+} (Cmol/kg)	K^+ (Cmol/kg)	Na^+ (Cmol/kg)	CEC (Cmol/kg)	H^+ (Cmol/kg)	Al^{3+} (Cmol/kg)	Avail P ($mg.kg^{-1}$)
Contamination													
Contaminated	6.44	5.98	6.07	10.46	0.09	2.78	0.68	0.11	0.21	184	0.95	0.53	9.4
Uncontaminated	6.78	6.12	1.41	3.53	0.11	4.23	0.93	0.12	0.16	147	0.73	0.3	14.23
LSD (P<0.05)	0.3	Ns	1.44	2.49	0.01	ns	0.17	Ns	0.03	Ns	Ns	0.19	2.34
Location													
Nsukka	6.51	6	4.02	6.92	0.1	1.75	0.88	0.09	0.16	153	0.68	0.45	7.46
Ngwo(9^{th} mile)	6.58	5.94	3.35	5.77	0.09	5.1	0.73	0.14	0.21	186	0.72	0.53	14.7
Obollo- afor	6.65	6.21	3.85	8.3	0.11	3.68	0.83	0.12	0.18	156	1.12	0.28	13.29
LSD(P<0.05)	Ns	Ns	Ns	Ns	Ns	2.32	Ns	0.03	0.04	Ns	Ns	Ns	2.87
Soil depth													
0- 20cm	6.72	6.07	3.43	7	0.11	3.85	1.13	0.12	0.19	158	0.97	0.38	11.75
20- 40cm	6.51	6.03	4.05	6.99	0.09	3.17	0.48	0.12	0.18	173	0.72	0.45	11.89
LSD (P<0.05)	Ns	Ns	Ns	Ns	0.01	1.9	0.17	ns	ns	Ns	Ns	Ns	Ns

OC, organic carbon; OM= organic matter, Total N= total nitrogen, Ca^{2+} = calcium, Mg^{2+} = magnesium K^+ = potassium, Na^+ = sodium, CEC = cation exchange capacity, H^+ = hydrogen, Al^{3+} = aluminum, Avail P = available phosphorus, Ns= not significant.

lead (Pb) to maize plants. Iron (Fe) quotient (0.87) was less than 1, indicating hazard effect that is not likely. These results are in line with the report by Lindsay and Norwell (1977), which showed critical levels (hazard quotient) of heavy metals for corn as: 0.8 ppm for Zn, 4.5 ppm for Fe, 1.0 ppm for Mn and 0.2 ppm for Cu.

Table 5 presents the effects of crude oil contamination on the germination and yield indicators (height and leaf area) of maize. It took longer days for maize seedling emergence on untreated polluted soils, given the value at 8 days compared to 4 days in unpolluted soils treated with compost manure (CM) (control). This suggests inhibited germination rate with higher oil pollution. At one week after sowing (1 WAS), percentage emergence of seedlings was 87.3% in control when compared to 15% of polluted soil.

The percentage survival rate in 2-3 weeks after sowing was 87.3% in control, 68.45% in unpolluted soil without CM, 32.41% in polluted soil with CM, and 8.50% in polluted soil without CM. The percentage significant (P<0.05) reduction in emergence and survival rates could be associated to a number of reasons: High critical levels (HQ>1) of the heavy metals that showed likelihood of harmful effects; the embryo of the seed been affected when in contact with crude oil, and high content of aromatics in the crude oil explaining the growth inhibition of seedlings. Similar reports have been made (Udo and Fayemi, 1975; Vwioko and Fashemi, 2005).

At eight days after sowing (8 DAS), maize seedlings were 4.2 cm long in untreated polluted soil, giving a 37.4% (-7.18 cm) decrease in comparison with the control. During the same period, leaf area significantly (P<0.05) decreased by 81.7% (-5.93 m^2) relative to manure treated unpolluted soil (Table 5). Maize seedlings on polluted soils began to turn yellow at 9 days and necrotic at 19 DAS, while those of control plot started yellowing at 3 WAS (21 days) but showed recovery signs thereafter.

There were significant (P<0.05) differences and reductions in the plant height and leaf area of maize seedlings in the polluted soils and those of non-polluted soils (Table 5). Poor growth performance of the maize seedlings in polluted soils could be due to heavy metals bioaccumulation, although not significant (Table 3). These results are in line with previous reports (Vwioko and Fashemi, 2005) that crude engine oil waste polluted soils could become unsuitable for plant growth due to a reduction in the level of available plant nutrients or rise in the toxic level of elements, all of which affected plant height and leaf area. Zinc element may be highly implicated in this study as toxicity symptoms of zinc include chlorosis and depressed plant growth.

Dry matter weight of the maize seedlings significantly (P<0.05) decreased from 6.79 g in treated unpolluted soil through 0.48 g in polluted without CM soil, representing 92.9% (-6.31 g) decrease. Better performance of the maize seedlings in unpolluted soils could be associated to added soil amendment, and which may have contributed to increased microbial activities.

Examination of the prevalent microorganisms revealed high presence of bacteria such as *Achromobacter, Clostridium, Bacillus subtilis, Sarcina and Micrococcus*; Fungi like dark green dusty colonies of *Aspergillus fumigatus, A. niger, Penicillium* spp.*, Geotrichum* spp.*,* and T*richoderma* spp. as well as Actinomycetes , *Norcadia spp and Streptomycetes.* These microbes identified as active members of bioremediation microbial consortia (Ekundayo and Obuekwe, 1997; Osu and Okereke, 2010) may have been involved in the bioremediation process in this study.

Table 3. Effects of contamination, location and soil depth on soil trace elements and heavy metal.

Soil sample	Boron (ppm)	Copper (ppm)	Lead (ppm)	Zinc (meq/100g)	Manganese (ppm)	Iron (ppm)
Contamination						
Contaminated	2.63	2.98	0.10	3.92	3.20	3.90
Uncontaminated	3.02	2.29	0.04	2.97	2.91	2.05
LSD(P<0.05)	0.004	0.002	0.002	0.04	0.06	0.04
Location						
Nsukka	2.56	4.31	0.07	2.60	2.70	5.46
Ngwo(9th mile)	3.17	2.13	0.10	4.10	2.35	1.68
Obollo- afor	2.75	1.46	0.04	4.20	4.20	1.82
LSD(P<0.05)	0.004	0.002	0.002	0.44	0.07	0.044
Soil depth						
0- 20cm	3.04	3.36	0.09	3.67	2.90	3.92
20- 40cm	2.61	1.91	0.05	3.60	3.27	2.05
LSD(P<0.05)	0.004	0.002	0.002	Ns	0.06	0.04

Figures in parenthesis represent heavy metal values at 4 weeks after sowing.

Table 4. The effect of soil amendment on polyaromatic hydrocarbon (PAH) content of soil.

PAH (mg/l)	Contamination (initial)	3 month
Acenaphthene	0.2461	0.2117
Cenaphthylene	0	0.2148
Anthracene	0	0
Benzo (a)pyrene	1.8062	0.5931
Chrysene	0	0
Fluorene	0	0
Naphthalene	0.1274	0
Phenanthrene	1.2082	0.3229
Pyrene	2.4150	0
Total	5.8029	1.3425

Table 5. Effect of contamination on the germination, survival rate, plant height, leaf area and dry matter yield of maize seedlings

Treatment	Number of days taken for seedling emergence	Percentage emergence at 1 WAS (%)	Height of emergent in 8; 21 DAS (cm)	Leave area (m^3) in 8; 21 DAS (cm	Percentage survival of emergent at 2WAS	1st Day of noticed yellowing in plants	Dry matter weight (g)
Contamination without CM	6	14.68	4.2; 7.0	1.33; 5.6	8.51	9	0.48
Contaminated with CM	5	54.30	6.7; 11.9	2.83; 5.57	32.44	11	1.72
Uncontaminated without CM	4	72.60	11.0; 15.7	5.90; 20.14	68.45	17	4.85
Uncontaminated with CM	3	87.28	13.5; 19.2	7.26; 27.20	87.26	21	6.79
FLSD (P<0.05)			1.726; 3.467	0.947; 3.319			3.63

DAS, days after sowing; WAS, week after sowing; CM, compost manure.

Microorganisms grow on substrates such as compost manure and produce enzymes that metabolize the hydrocarbons in the compost matrix (Diaz et al., 1996). Remon et al. (2005) observed that increased activities of microorganisms cause improved enhance-ment of structure, water retention, permeability, drainage and aeration of soils.

Conclusion

This study reveals high levels of heavy metals that affected seedlings emergence, resulting to low survival percentages and high bioaccumulation quotient. There were high decreases in soil total poly aromatic hydrocarbon from original concentration. Values of maize growth parameters (height, leave surface) improved in both unpolluted and polluted soil added compost manure. Study identified active members of bioremediation microbial consortia that increased microbial activities, enhanced hydrocarbon decomposition and improved physical, chemical characteristics productivity of the soils in terms of yield.

High hazard quotients (HQ > 1) of trace elements pose ecological risks to maize production. Therefore, paradigm shift to sustainable biological soil systems management is desired. Also, mechanic villages should be situated several kilometers away from major land uses to protect soil resources, ensure environmental sanity and sustainability.

Conflict of interests

The author(s) have not declared any conflict of interests.

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