Journal of
Bioremediation & Biodegradation

Nwite et al., J Bioremediat Biodegrad 2016, 7:3
DOI: 10.4172/2155-6199.1000350

Research Article | Open Access

Remediation of Crankcase Oil Contaminated Soil with Different Sources of Manure in Abakaliki, Southeast, Nigeria

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Abstract

Remediation of crankcase oil contaminated soil with different sources of manure was studied using randomized complete block design with four treatments which were replicated five times. Oba super ∏ hybrid variety of maize was used as a test crop. Results showed significant (P<0.05) treatment effect on aggregate stability, gravimetric moisture content (GMC), available phosphorus, calcium and cation exchange capacity (CEC) as well as plant height and grain yield of maize relative to control. Significantly (P<0.05) higher aggregate stability, GMC, Calcium and CEC were obtained in plots receiving a combination of poultry droppings and NPK fertilizer compared to other sources of manure and control. Aggregate stability, GMC, Ca, CEC and organic carbon were higher by 12, 47, 75, 66 and 20% respectively in plots amended with combination of poultry droppings and NPK fertilizer when compared to the control. Grain yield of maize was 44, 36 and 40% higher in plots amended with combined poultry droppings and NPK fertilizer compared to the control, poultry droppings and NPK fertilizer amended plots. Remediation of crankcase oil contaminated soil could be achieved through manure amendment for increased and sustainable productivity.

Keywords: Amended; Contaminated; Crankcase oil; Different sources; Manure; Remediation

Introduction

Contamination is any physical, chemical, biological and radiological material introduced into the soil [1] either anthropogenically or naturally. Crankcase oil is the waste oil produced after the servicing of automobile vehicles and is regarded as condemned or spent engine oil in different parts of the world. The oil could also be generated from ruptured underground storage tanks, motor wheels, and chain wheels or lubricated metal parts by motor mechanics or during farming operations by automobiles [2]. These waste oils once in the soil become part of the biological cycle that affects the productive capacity of soil [3] effecting the habitat, including crops. The contamination of soil with crankcase oil affects soil properties which include bulk density, soil porosity, infiltration rate, hydraulic conductivity, moisture content and soil pH, organic carbon, nitrogen as well as other major nutrients and microbial activities of soil [4].

Furthermore, previous studies had revealed that oil contamination resulted in insufficient aeration of the soil due to the displacement of air from the space between the soil particles [5]. This often retards growth of plants and also results in chlorosis of leaves and dehydration of plants [6].

Remediation of oil contaminated soil can be described as the application of suitable techniques in the removal of such contaminants present in soil [1]. Bioremediation is the use of organic wastes to reclaim and increase the productivity of hydrocarbon contaminated soil. According to Ref. [7], organic materials when added to oil contaminated soil biostimulates microbial degradation of the hydrocarbon oil. Today bioremediation has proved to be efficient, effective and environmentally friendly means of remediation of oil contaminated soil [7] than physical and chemical methods. Although, studies have been carried out on remediation of oil contaminated soil, however, it is by no means exhaustive. Besides, remediation of crankcase oil contaminated soil has not been well documented in literature in Abakaliki. The objectives of this study were to bridge this gap in knowledge and therefore raise awareness of critical stakeholders and land managers in the agro-ecology of availability of new techniques to remediate crankcase oil contaminated soil as well as evaluate maize yield in Abakaliki agro-ecological environment.

Materials and Methods

Experimental site

The experiment was carried out at the Teaching and Research farm of the Faculty of Agriculture and Natural Resources Management, Ebonyi State University, Abakaliki. The site is located by latitude 06°4' N and longitude 08°65' E in derived savannah of the South east agro ecological zone of Nigeria. The area experiences a bimodal pattern of rainfall which is spread from April-July and September-November with a short spell in August. The total annual rainfall ranges from 1700 mm to 2000 mm. The minimum and maximum temperatures are 27°C and 31°C, respectively. Relative humidity is 80% during the rainy season but declines to 60% in the dry season [8]. The soil is derived from sedimentary rock as the Abakaliki agroecological zone lies within "Asu River" from tertiary and cretaceous period. The soil is underlain by shale deposit and consists of olive brown sandy shale, fine grained sand stones and mudstone. The soil belongs to the order ultisol classified as Typic Haplustult [9].

Experimental design/treatment application

The land area which measured 12 m × 15 m and approximately 0.02 ha was used for the experiment. The site was cleared with cutlass and debris removed. The experimental site was spread with 50,000 $mgkg^{-1}$ of crankcase oil sourced from mechanic site in Abakaliki

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Received March 21, 2016; **Accepted** April 19, 2016; **Published** April 24, 2016

Citation: Nwite JN, Aya FC, Okolo CC (2016) Remediation of Crankcase Oil Contaminated Soil with Different Sources of Manure in Abakaliki, Southeast, Nigeria. J Bioremediat Biodegrad 7: 350. doi: 10.4172/2155-6199.1000350

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before cultivation. This was done using hand knapsack sprayer. The crankcase oil was allowed to penetrate into the soil for two weeks. The experiment was laid out in a Randomized Complete Block Design. The field was demarcated into plots that measured 3 m × 2 m and spaced 0.5 m apart. The treatments namely Control (C), poultry droppings (PD), NPK 15:15:15 fertilizer (NPK) and poultry droppings mixed with 400 kgha^{-1} of NPK 15:15:15 (PD+NPK) were replicated five times to give a total of twenty experimental plots. The replications were set apart by a 1 m alley. The treatments were applied at 10 tha^{-1} of poultry droppings equivalent to 6 kg plot^{-1}, 400 kgha^{-1} of NPK 15:15:15 fertilizer equivalent to 12 kg plot^{-1} and a combination of poultry droppings and NPK 15:15:15 fertilizer. The amendment materials were spread on the plots and incorporated into the soil during seedbed preparation using traditional hoe.

Planting

A hybrid variety of maize (Oba super 11) sourced from Ebonyi State Agricultural Development Programme (EBADEP) Onuebonyi Izzi, Abakaliki was used as a test crop. The maize seeds were planted at two seeds per hole at a depth of 5 cm in each plot and spacing of 25 cm × 75 cm after two weeks of treatment incorporation. The maize seedlings were thinned down to one plant per hole after two weeks of germination. Weak ones were replaced by replanting to give plant population of 24 stands per plot and approximately 53,333 plants per hectare.

Soil sampling

Initial soil samples were randomly collected with auger from the site at depth of 0-20 cm and composited for pre-planting soil analysis. Core and auger samples were also collected at three points in each plot at 0-20 cm depth while plants were still in the field for post-harvest soil analysis.

Agronomic data

Twelve plants from a net plot representing 25% of plant population per plot were used for the study. Plant height was measured at two weekly intervals until crop maturity using a calibrated meter rule. At maturity, when the maize husks had turned brown and dry, the cobs were harvested, dehusked, shelled and grains further dried and grain yield determined at 14% moisture content.

Laboratory methods

Physical properties: Core samples were used to determine some physical properties of the soil. Bulk density was determined using the Blake and Hartge [10] method. Total porosity and gravimetric moisture content were determined as described by Obi [11]. Aggregate stability was determined using Kemper and Chepil [12] method.

Chemical properties: Auger samples were used to determine chemical properties of the soil. The auger samples were air-dried, crushed and passed through a 2 mm sieve and particles <0.2 mm were subjected to analysis. Total nitrogen was determined using micro-kjedhal procedure according to Bremner [13]. Phosphorus was determined using the Bray-2 method as described in Page et al. [14]. Exchangeable sodium and potassium were determined using flame photometry method of Ohiri and Ano [15]. Exchangeable calcium and magnesium were determined using the titration method as described by Mba [16]. Organic carbon was determined according to the Nelson and Sommer [17] procedure. Cation exchange capacity was determined using ammonium acetate (NH_4OAC) displacement method of Jackson [18]. Base saturation was calculated as follows:

$$\%BS = \frac{\text{Exchangeable bases}}{\text{Cation exchange capacity } 1} \times 100$$

Where BS=Base saturation.

Heavy metals of Pb, Cu, Zn and Cd in crankcase oil and soil were determined using atomic absorption spectrophotometer according to Dewis and Freitas [19] procedure.

Data analysis

Data from the field and laboratory were analyzed using analysis of variance (ANOVA) for randomized complete block design. Treatment means which were significant were further tested using Fisher's Least Significant Difference (F–LSD) as described by Steel and Torrie [20]. Significant treatment effect was accepted at 5% probability level.

Results and Discussion

Initial properties of soil and crankcase oil

Table 1 shows initial properties of soil before contamination and crankcase oil. The results showed that sand fraction was dominant in particle size distribution with low clay content. Textural class of the soil is sandy loam. The soil had a pH of 5.20. The available phosphorus content was 15.50 mgkg^{-1}. The percentage nitrogen was low with a value of 0.06%. Organic carbon content and organic matter content were respectively 1.56 and 2.72%. The respective values for exchangeable Calcium, Magnesium, Potassium, and Sodium were 5.60, 2.80, 0.16 and 8.91 cmolkg^{-1} with cation exchange capacity (CEC) and base saturation values of 8.91 cmolkg^{-1} and 98%. These low trends of chemical properties show that the soil is degraded with low fertility. This could partly be attributed to continuous cultivation as well as poor management of the soil which is now endemic in our farming system due to pressure on land resulting from over population.

Heavy metals content of crankcase oil indicated that lead and zinc dominated cadmium and copper in the oil. However, the value of heavy metals content of crankcase oil fell below the critical and

Soil Properties	Unit	Value
Sand	gkg^{-1}	76.0
Silt	gkg^{-1}	14.0
Clay	gkg^{-1}	10.0
Textural class		Sandy loam
pH (H_2O)		5.20
P	mgkg^{-1}	15.50
N	%	0.06
OC	%	1.56
OM	%	2.72
Ca	cmolkg^{-1}	5.60
Mg	Cmolkg^{-1}	2.80
K	Cmolkg^{-1}	0.16
Na	Cmolkg^{-1}	0.20
CEC	Cmolkg^{-1}	8.91
BS	%	98
Crankcase oil		
Cd	mgkg^{-1}	
Cu	mgkg^{-1}	11.31
Pb	mgkg^{-1}	14.27
Zn	mgkg^{-1}	30.33

OC - Organic Carbon; OM - Organic Matter

Table 1: Initial properties of soil and crankcase oil.

recommended levels that could be injurious to plants, livestock and even mankind [21].

Soil physical properties

Table 2 shows effect of different sources of manure on soil physical properties contaminated with crankcase oil. There were no significant (P<0.05) differences in bulk density among the treatments. Control plot had highest bulk density of 1.50 mgm^{-3} and this was higher by 5 and 6% than the values obtained in plots amended with of poultry droppings and a combined of poultry droppings and NPK fertilizer. The total porosity followed the trend obtained in bulk density. The plot amended with a combination of NPK fertilizer and poultry droppings was 19% each higher in total porosity when compared to the control and the plot amended with NPK fertilizer alone.

The combined fertilizer and NPK fertilizer treated plots had an improved aggregate stability of 12% and 11% respectively when compared to the control. These plots were also 12% and 18% higher in GMC when compared to single fertilizer treatments.

The significant positive effect of different sources of manure amendment on aggregate stability and GMC of crankcase oil contaminated soil has been reported before [5,22-24] Similarly, positive improvements recorded in plots contaminated with crankcase oil and amended with different sources of manure when compared to control are intandem with the findings of Ref. [25-28] reported that low soil porosity was one of the fertility problems of oil contaminated soil which often occurs as a result of compaction resulting in high bulk density. The superior improvements in soil properties in plots amended with a combined poultry droppings and NPK fertilizer compared to other manure treatments could be attributed to its effectiveness and efficiency in attenuating and remedying soil contaminated with crankcase oil. This could be linked to higher mineralization of nutrients from the treatments into the soil that stimulated more microbial action to degrade the hydrocarbon oil which was corroborated by Mbah [22]. The non-significant treatment effect on bulk density and total porosity implies that manure sources could not be used to remedy compaction and porosity of crankcase oil contaminated soil to levels they would not impose limitation to productivity.

Treatments	Bulk density (mgm^{-3})	Total Porosity (%)	Aggregate Stability (%)	GMC (%)
C	1.50	43	37.95	9.0
PD	1.42	47	37.85	15.0
NPK	1.50	43	37.60	14.0
PD+NPK	1.41	47	42.67	17.0
FLSD($_{0.05}$)	NS	NS	0.77	0.27

Where, C - Control; PD - poultry droppings; NPK - NPK fertilizer; GMC - gravimetric moisture content; NS - Not Significant.

Table 2: Effect of different sources of manure on soil physical properties contaminated with crankcase oil.

Soil chemical properties

Table 3 shows effect of different sources of manure on soil chemical properties contaminated with crankcase oil. Results indicated that treatments had significant (P<0.05) effect on available phosphorus, calcium and cation exchangeable capacity (CEC), but no significant increase in nitrogen or organic carbon was evident. The plot amended with NPK fertilizer was 6% each higher in soil pH when compared to values of those amended with poultry droppings and a combination of poultry droppings and NPK fertilizer. Furthermore, significant (P>0.05) differences were observed in available phosphorus in plots amended with different sources of manure. The plot amended with poultry droppings was 22% higher in available phosphorus when compared to control and plots receiving NPK fertilizer and combination of poultry droppings and NPK fertilizer, respectively.

The organic carbon content of plot amended with a combination of poultry droppings and NPK fertilizer was higher by 20, 19 and 25% when compared with control, plots amended with poultry droppings and NPK fertilizer.

There were significant differences in calcium among the treatments. Similarly, the plot amended with combination of poultry droppings and NPK fertilizer was 75, 30 and 50% higher in calcium when compared to control, plots amended with poultry droppings and NPK fertilizer, respectively. Plot amended with NPK fertilizer was respectively higher in Mg, K and Na by 57, 19 and 31% relative to control and also varied from other treatments. Cation exchange capacity of plots receiving amendments was significantly (P<0.05) higher than control.

The plot amended with a combination of poultry droppings and NPK fertilizer was respectively higher by 18, 34 and 66% in CEC when compared with the plots amended with poultry droppings, NPK fertilizer and control. Base saturation was 5 and 4% higher in base saturation in plot amended with combination of poultry droppings and NPK fertilizer compared to control and plots amended with poultry droppings.

The no significant treatment effect obtained in soil pH, Nitrogen, organic carbon and exchangeable Mg, K, Na and BS could be attributed to low fertility trend of soil used for study and effect of crankcase oil contamination. It further implies that the amendments were not effective and efficient enough to attenuate the problem of crankcase oil contamination on these soil properties Vuoto et al. [25]. had earlier reported that fertility problem in soil contaminated with spent lubricant oil due to the fact that it contained toxic materials which affected Nitrogen, organic carbon exchangeable, Mg, K, Na and BS as well as some other nutrients in the soil which affect inherent productivity of soil.

The low nitrogen in soil is in line with the report of Atuanya [29] who pointed out that nitrogen was not significantly affected by amendments in oil contaminated soil. Low nitrogen obtained in plot amended with a combination of poultry droppings and NPK fertilizer

Treatment	pH (H_2O)	P mg/kg	N%	OC%	Ca	Mg	K	Na	CEC	% BS
					cmolkg^{-1}					
C	6.00	15.70	0.06	1.45	2.00	1.20	0.13	0.09	3.81	91
PD	6.30	20.00	0.08	2.34	5.60	2.40	0.12	0.13	9.05	92
NPK	6.40	18.60	0.08	2.14	4.00	2.80	0.16	0.13	7.35	96
PD+NPK	6.30	17.90	0.07	2.87	8.00	2.40	0.12	0.11	11.09	96
FLSD (0.05)	NS	0.27	NS	NS	0.20	NS	NS	NS	0.35	NS

C - Control; PD - poultry dropping; NPK - NPK fertilizer; NS - Not Significant

Table 3: Effect of crankcase oil contamination amended with difference sources of manure soil chemical properties.

relative to values obtained for those receiving poultry droppings and NPK fertilizer could be attributed to higher microbial activities which led to immobilization of nitrogen into microbial tissues for degradation of hydrocarbon oil. Several authors [30-32] had reported low total nitrogen, organic carbon and soil pH in soil contaminated with spent lubricant oil. Low values of Na, K and Mg were noted by Nwite [33] in his study of soil contaminated with automobile oil. Exchangeable Na, K and Mg can enter into complexes with other elements and this could be one of the reasons for their low values in the soil. Tiger et al. pointed out that Na was particularly low in soil contaminated with hydrocarbon oil due to its immobilization. The significant treatment effect on available P, exchangeable Ca, cation exchangeable capacity (CEC) suggests that the amendments have the potentials to restore crankcase oil degraded soil by increasing these nutrients in the soil. The significant effect of treatments on available phosphorus could further be attributed to improvements on soil pH and organic carbon of amended plots (Table 3). This is because high pH and organic carbon in soil has positive influence on soil available phosphorus. Significant exchangeable Calcium could be attributed to characteristic of strongly weathered soils of the tropics and already high calcium content at pre-planting period. This finding is in line with the observation of Ref. [30]. Abii and Nwosu that calcium was high and significant due to strongly weathered characteristics of tropical soils. The significant CEC could be attributed to positive effects of amendments on one hand and improved values of soil pH, available phosphorus, organic carbon and exchangeable Ca, Mg and Na on the other (Table 3). Superior performance of combination of poultry droppings and NPK fertilizer treatment on improving nutrients of soil compared to other treatments could linked to higher mineralization which spurred higher microbial degradation of hydrocarbon oil. This finding is in line with the report of Adesodun [1] that higher microbial action on hydrocarbon oil increased soil productivity.

Heavy metals concentration in soil

Table 4 shows effect of different sources of manure on heavy metals concentration of soil contaminated with crankcase oil. Results indicate that there was no significant ($P<0.05$) treatment effect on heavy metals concentration of soil. Heavy metals of control were higher than the values obtained in amended plots, respectively. The values of Pb are 25, 33 and 55% higher in control compared to plots amended with poultry droppings, NPK fertilizer and combination of droppings and NPK fertilizer. Cadmium was 10 and 20% higher in control relative to plots amended with NPK fertilizer and combined poultry droppings and NPK fertilizer.

Higher concentration of Pb and Cd in control relative to amended plots indicates that crankcase oil contamination could be remedied through different sources of manure amendments. This finding is in line with Anikwe [34] who reported that organic wastes could be used to ameliorate heavy metals concentration in soil contaminated with spent lubricant oil and increase its productivity. Low values of Pb and Cd in amended plots compared to control could be attributed to adsorption by materials provided by the amendments into the soil. Jones et al. [35] pointed out that heavy metals were adsorbed at particle surface or to carbonates as well as occluded in iron or manganese oxides, organic matter or sulphide. This was corroborated by Anikwe [36]. In his findings where he noted that heavy metals were chelated by organic matter and thus reduced its presence in the soil. The Pb and Cd in soil are higher than low levels of 0.0-0.1 and 0.0-0.003 recommended by LASEPA to be safe to life. Lead and Cadmium are lower than recommended high values by WHO for ecotoxicity.

Maize plant height

Table 5 shows effect of different sources of manure on plant heights of soil contaminated with crankcase oil at 2, 4, 6, 8 and 10 weeks after planting (WAP). The result showed significant ($P<0.05$) treatment effect on plant height relative to control at different sampling periods. Similarly, there were significant ($P<0.05$) differences among treatments in plant height at different sampling periods. The plot amended with a combined poultry droppings and NPK fertilizer had tallest maize plant at 2, 4, 6 and 10 WAP compared to control and plots amended with poultry droppings and NPK fertilizer, respectively. These were 34, 27, 16%; 35, 13, 20%; 2, 31, 12% and 14, 22, 16% respectively taller maize plants in plot amended with combined poultry droppings and NPK fertilizer compared to control, plots amended with poultry droppings and NPK fertilizer. Conversely, at 8WAP, maize plant was taller in plot amended with NPK fertilizer compared to control and those treated with poultry droppings and combined poultry droppings and NPK fertilizer. This represents 12, 17 and 32% increments in maize plant heights relative to control, plots receiving poultry droppings and a combined poultry droppings and NPK fertilizer.

Significant treatment effects obtained in plant heights at different sampling periods in plots amended with different sources of manure relative to control could be attributed to positive impacts of the amendment materials in improving and ameliorating crankcase oil contamination of soil. The significant differences obtained in plant height in plots receiving different sources of manure treatment implies that the manure sources have differential potentials to remedy crankcase oil contamination and cause increase in maize plant height. Even though, the manure sources remedied crankcase oil contamination, the combined manure source of poultry droppings and NPK fertilizer was more superior in attenuating crankcase oil contamination through improved soil properties (Tables 2 and 3) and higher maize plant (Table 5). This finding is supported by Nwite [33]. observation that of all amendments to ameliorate automobile oil contamination, burnt rice mill waste proved superior to other wastes in improving and sustaining soil productivity.

Grain yield of maize

Table 6 and Figure 1 show effect of different sources of manure on

Treatments	Pb	Cd
	mgkg^{-1}	
C	0.12	0.10
PD	0.09	0.10
NPK	0.08	0.09
PD + NPK	0.06	008
FLSD$_{(0.05)}$	NS	NS

C - Control, PD - poultry droppings, NPK - NPK fertilizer, NS - Not Significant

Table 4: Effect of different sources of manure on heavy metals of soil contaminated with crankcase oil.

Treatments	2WAP	4WAP	6WAP	8WAP	10WAP
C	7.6	32.5	60.6	69.8	157.7
PD	8.5	43.4	44.7	65.4	142.7
NPK	9.7	40.1	56.9	79.2	153.6
PD+NPK	11.6	50.0	64.6	53.6	183.4
FLSD$_{(0.05)}$	0.4	2.3	4.3	4.8	6.3

Where, C - Control; PD - poultry dropping; NPK - NPK fertilizer; NS - Not Significant

Table 5: Effect of different sources of manure on maize plant height of soil contaminated with crankcase oil.

Treatments	Grain yield t ha^{-1}
C	1.34
PD	1.54
NPK	1.45
PD+NPK	2.41
F-LSD ($_{005}$)	0.71

Where: C - Control; PD - Poultry dropping; NPK - NPK fertilizer

Table 6: Effect of different sources of manure on grain yield of maize of soil contaminated with crankcase oil.

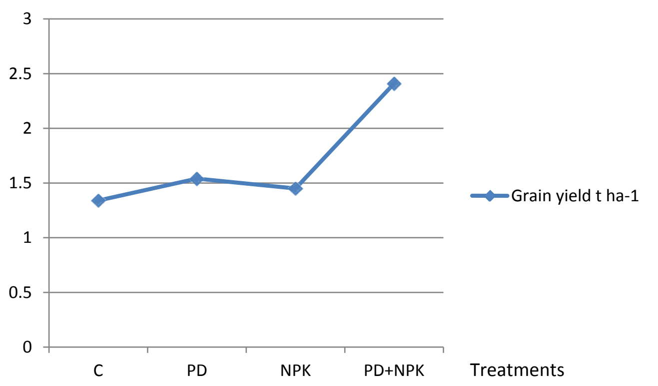

Figure 1: Grain yield of maize (tha^{-1}).

grain yield of maize of soil contaminated with crankcase oil. Results indicated that grain yield of maize in amended plots was significantly ($P<0.05$) higher than control. Significantly ($P<0.05$) higher grain yield of maize was obtained in plot amended with a combination poultry droppings and NPK fertilizer when compared with control, plots treated with poultry droppings and NPK fertilizer, respectively. This was 44, 36 and 40% respectively higher than the control, plots amended with poultry droppings and NPK fertilizer. The increase in grain yield of maize is as follows PD+NPK>PD>NPK>C in the treatments.

The low grain yield in control could be due to poor physical and chemical properties of the soil (Tables 2 and 3). This implies low nutrient utilization in the soil [37]. Similarly, Brady and Weil [3] noted that productive capacity of soil contaminated with spent lubricant oil was degraded. Mbah et al. [4] reported low maize grain yield in spent oil contaminated soil. The significant increase in grain yield of maize in plots treated with different sources of manure and particularly one receiving combined poultry and fertilizer treatment could be linked to improvements in physical and chemical properties of soil (Tables 2 and 3). Similar observations were made [23,27,38] of significant increase in grain yields of maize in soil amended with organic wastes. The grain yields of maize were below global maize yield of 2.5 tha^{-1} [39] and high value according to the recommendation of NPAFS [40,41] under different sources of manure treatment and control.

Conclusion

The result of this study had shown that amendment of soil contaminated with crankcase oil with different sources of manure improved soil properties and agronomic yield of maize and generally its productivity. Significantly higher effect of treatments was obtained on aggregate stability, gravimetric moisture content, available phosphorus, exchangeable calcium, cation exchange capacity, maize plant height and grain yield of maize in amended plots relative to control. Comparatively, the plot amended with combined sources of manure of poultry droppings and NPK fertilizer had superior performance in increasing and sustaining soil productivity when compared to other treatments. It could be recommended that different sources of manure be used to ameliorate and sustain productivity of soil contaminated with crankcase oil.

Acknowledgements

The authors graceful acknowledge the laboratory attendants' for their invaluable assistances at various stages of this work. We remain grateful to all of you.

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