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Research Article

Effects of Contamination of Soil with Used Engine Oil on Some Soil Properties and Microbial Growth in Wukari, North Eastern Nigeria

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Abstract: This experiment was carried out in Wukari which is located at latitude 7.85^{o}N and Longitude 9.78^{o}E. The study aimed at assessing the effects of contamination of the soil with used engine oil on selected soil chemical properties and microbial population in the soil. The experiment was set up in a completely randomized design in 3 replicates. The treatments consisted of 3 kg soil samples contaminated with 187.5, 375.0, 562.0 and 750.0 milliliters of used engine oil, which is equivalent to 125,000.0, 250,000.0, 375,000.0 and 500,000.0 liters of used engine oil per hectare respectively. There were two control treatments, soil without used engine oil added to it and soil contaminated with used engine oil collected from the mechanic village site in Wukari. The soil samples were maintained at field capacity for four weeks, there after soil samples were collected for analysis using standard techniques. Contaminated soils depicted significant ($P < 0.05$) increase in organic carbon, organic matter, total nitrogen and pH compared to the control where no engine oil was added. The result also gave a significant ($P < 0.05$) decrease in phosphorus, potassium, calcium, magnesium and exchangeable acidity compared to the control. However, the application of contaminated engine oil did not significantly ($P > 0.05$) affected the microbial population in all the treatments.
Keywords: Microbial population, soil chemical properties, soil contamination, used engine oil, North Eastern Nigeria.

INTRODUCTION

Soil is a primary recipient of a myriad of waste products and chemicals used in modern industrial society (Brady and Weil, 2002). Modern industrialized societies have developed plastics and plasticizers, automobiles and refrigerants, fuels and solvents, pesticides and preservatives. Organic chemicals may enter the soil as contaminants in wastes applied on soils or as fertilizer (Lauhanen *et al.*, 2004), in large or small automobile oil and fuel leaks and as sprays applied to control pests (Adesodun, 2004). Some of these wastes; fertilizers, automobile oil, fuel leaks, pesticides, preservatives etc. are toxic even in very small concentrations. Once waste materials enter the soil, they become part of a biological cycle that affects all forms of life. Contamination of a soil with toxic substances can degrade its capacity to provide habitat for crops (Brady and Weil, 2002).

In Nigeria, the common sources of soil contamination are household wastes, agricultural wastes, gas flaring and used automobile oil. Soil and water contamination by crude oil is a sensitive issue, particularly in the Niger-Delta areas. Crude oil is physically, chemically and biologically harmful to soil because it contains many toxic compounds in relatively high concentrations (Franco *et al.*, 2004). Soil contamination can result in soil degradation, bring great loss to agricultural production and pose threat to human health (Lijuan, 2012). Crude oil spill is a common event in Nigeria especially in the Niger Delta areas of the country. Spills may arise from oil well drilling, production operations, transportation, refining, storage and marketing. It could also be from anthropogenic sources such as sabotage or accidental spills such as ruptured oil pipelines (Oberdorster and Cheek, 2000).

The impact of contamination by spent automobile oil in the environment has been shown to be more widespread than contamination by crude oil (Nwite, 2013). For instance, Nigeria was reported to account for more than 87 million liters of spent oil waste annually and adequate attention has not been given to its disposal (Anoliefo and Vwioko, 2001).

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Contamination of soil and groundwater with spent automobile oil otherwise called “condemned” engine oil obtained after servicing of automobiles is a common phenomenon in the mechanic village, popularly known as “new site” in Wukari. The spent automobile oil is disposed off indiscriminately into the surrounding environment by “motor mechanics”.

Microorganisms are important for soil quality and fertility. They play a major role in decomposition of organic matter, degradation of chemical pollutants and mineralization in the soil. Amongst the different microorganisms inhabiting the soil, bacteria are the most abundant and predominant organisms. Bacteria and other microbes are chemical processors, tiny biotechnologists, capable of catalyzing thousands of chemical reactions that higher organisms are incapable of mediating. It has been reported that bacteria constitute the principal agents of hydrocarbon biodegradation (Agbo, 2015). It is well known that soil micro flora and fauna can be manipulated indirectly through crop management practices. Similarly, cultivation of legumes leads to increased number of their compatible Rhizobia (Udom, 2008).

When spent engine oil is dropped into the soil, it not only kills off microbial life but can also make the soil impassible for worms and other small organisms. This inactivity leads to a lack of aeration in the soil that can literally suffocate soil until the affected area is a little more than dust. Soil polluted in this way is unsuitable for any growth, and contaminated areas have taken years and specialized treatment to recover fertility.

Spent engine oil causes great damage to soil and soil micro-flora. It creates unsatisfactory condition for life in the soil due to poor aeration, immobilization of soil nutrients and lowering of soil pH (Ugoh and Moneke, 2011). It has been shown that marked changes in properties occur in soil contaminated with hydrocarbon; this affects the physical, chemical and microbiological properties of the soil (Okonokhua *et al.*, 2007). At low concentrations, some of these heavy metals are essential micronutrients for plants, but they can cause metabolic disorders and growth inhibition when the concentration is high. Therefore, there is the need for bioremediation of hydrocarbon contaminated soil.

The specific objectives of the work are to:

- Assess some selected chemical properties of soil as affected by used engine oil contamination in the soil.
- Assess the bacterial and fungal population of the soil contaminated with used engine oil.

MATERIALS AND METHODS

Study Area

Wukari town is the Headquarters of Wukari Local Government Area of Taraba State, North Eastern Nigeria. It is located at the derived Savanna Agro Ecological Zone of Nigeria. It is located between Latitute 7.85^o N and Longitute 9.78^o E of the Equator with an elevation of 189 meters above sea level. The average annual temperature of Wukari is 26.8^{o}C, with an average annual rainfall of 1,205 mm (World Atlas and climate Data Org., 2015).

Collection of Materials

Used engine oil for this study was obtained from mechanic village (New site) along Takum road Wukari. The soil samples for the experiment were collected at 0 – 20 cm depth at the Teaching and Research Farm, Federal University Wukari, while the second control (contaminated soil) was collected from the mechanic village Wukari.

Treatments and Experimental Design

After air drying and sieving to pass through 2 mm sieve, three kilograms of the bulked soil samples collected from the Teaching and Research Farm were weighed into plastic bowls. Also, three bowls containing 3 kg of contaminated soils each collected from the mechanic village site.

The experiment consisted of 6 treatments replicated three times. There were two control treatments, the first one no engine oil was added, while the second one was the contaminated soil samples collected from the Mechanic village.

The remaining four treatments were treated with different rates of used engine oil.

E1 = Control 1 (soil sample without used engine oil)
E2 = Control 2 (Soil sample from mechanic village)
E3 = Treatment 3 (Soil sample treated with 187.5 mls of used engine oil)
E4 = Treatment 4 (Soil sample treated with 375.0 mls of used engine oil)
E5 = Treatment 5 (Soil sample treated with 562.5 mls of used engine oil)
E6 = Treatment 6 (Soil sample treated with 750.0 mls of used engine oil)

Soil sample preparation and establishment of the Experiment

The soil samples were moistened with water collected from the borehole at field capacity for one week. This was to allow the soils stabilize and establish itself with new pore spaces and structure. Eighteen plastic bowls were filled with 3 kg soils depending on the treatment. The contamination was done according to the treatments. The soils on the bowls were watered and maintained at field capacity to avoid total dryness. The experiment lasted for four weeks after contamination and at the end soil samples were collected from each treatment for chemical and microbial analysis. The samples were air-dried and made to pass through 2 mm sieve.

Soil physical and chemical Analysis

Particle size distribution was determined by the hydrometer method as described by Gee and Bauda (1986). The bulk density of the soil was determined through the core sampler method (George *et al.*, 2013). The pH was determined using the glass electrode pH meter (1:1) (George *et al.*, 2013). The total nitrogen was determined using the micro-Kjeldhal distillation method according to Bremner (1996). Available Phosphorus was determined by the Bray-1 method as described by George *et al.*, (2013). Also the soil organic carbon was determined by the Walkley and Black wet dichromate oxidation method (George *et al.*, 2013). The percentage organic matter was obtained by multiplying the value for organic carbon by the "Van Bemmeler factor" (1.724), which is based on the assumption that soil organic matter contains 58 % carbon (Allison, 1982).

Calcium and Magnesium were determined by EDTA titration method as described by Mba (2004). Sodium and Potassium were extracted with 1N ammonium acetate solution (NH_4OAC) and determined using the flame photometer (NRC, 1993). The total exchangeable acidity was determined through titrimetric method (Mclean, 2004).

Soil Microbial Analysis

The viable bacteria and fungi counts were isolated by serial dilution agar plate method (NRC, 1993). Frequency and occurrence of organisms were determined using the approach of Dung and Stephen (2010).

Data Analysis

The data collected was subjected to analysis of variance using Genstat V.6 package and the significant means were separated using the Duncan Multiple Range Test at 5% level of significance.

RESULTS AND DISCUSSION

Initial Physico chemical properties of the soil

Table 1 is the result of the chemical properties of soil before contamination with used engine Oil. The results showed that the soil texture is loamy sand. The bulk density was observed to be 16.3 g/cm^3, which is considered to be medium.

The pH value of the soil is 5.58, which is slightly acidic in nature. The organic carbon content is 10.0 g/kg, which is medium, while the organic matter is 16.80 g/kg which is considered to be very high. The total nitrogen is 0.57 g/kg, this is also considered to be medium. This gave a C:N ratio of 17.35:1, which is low and similar to what is obtainable in this region. The available P is medium (12.53 mg/kg) and potassium content is high (0.32 cmol/kg). The Ca and Mg contents (1.58 and 0.82 cmol/kg) which are low and medium compared to what has been reported by Chude *et al.*, (2011) for Nigerian soil.

Table 1: Physicochemical properties of the initial soil sample without used engine oil contamination.

Parameter	Values
Sand (g/kg)	826.3
Silt (g/kg)	100.0
Clay (g/kg)	73.7
Textural Class	Loamy Sand
Bulk Density (g/cm^3)	16.3
pH (water)	5.58
Organic Carbon (g/kg)	10.00
Organic Matter (g/kg)	16.80
Total Nitrogen (g/kg)	0.57
Carbon/Nitrogen ratio	17.35
Available Phosphorus (mg/kg)	12.53
Potassium (cmol/kg)	0.32
Calcium (cmol/kg)	1.58
Magnesium (cmol/kg)	0.82
Exchangeable Acidity (mMol/100g)	1.72

Effects of used Engine Oil Contamination on Selected soil Chemical Properties

The results presented in Table 2 clearly showed a significant ($P < 0.05$) increase in soil pH, organic carbon (OC) organic matter (OM) and total nitrogen (TN) contents of the soil compared to the control treatment where used engine oil was not added. Also as the concentration of used engine oil increased there was a gradual increase of these parameters, even though there was no significant ($P > 0.05$) difference among the treatments.

For soil pH, E5 (562.5 mls) gave the highest pH value which was not significantly ($P > 0.05$) different from other contaminated soil treatments. Diana *et al.*, (2004) noted that hydrocarbon oil contaminated soils had significantly higher pH values. Observing OC, OM, and TN E6 (750.0 mls) treatment gave the highest mean values which were also not significantly higher than the other contaminated treatments. The built-up of carbon and organic matter content of the contaminated soil may be as a result of the addition of the used engine oil to the soil and the presence of hydrocarbon in the used engine oil. This is same with the results obtained by Agbogidi *et al.*, (2007) and Stephen *et al.*, (2013) in spent lubricating oil polluted soil subjected to phytoremediation. Organic carbon serves as the source of energy for the metabolism of the oil from the soil. The increase in nitrogen content may be due to higher organic matter content in the used engine oil contaminated soils. This agrees with the findings of Stephen and Ijah (2011) and Stephen and Egene (2012). These researchers reported increase in nitrogen contents of soil polluted by hydrocarbons.

On the other hand, there was a significant ($P < 0.05$) decrease of phosphorus, potassium, calcium, magnesium and exchangeable acidity content on the soils contaminated with used engine oil compared to the control treatment E1 which had no used engine oil added to it. Among the contaminated soil treatments, the E6 (750 mls) that had the highest volume of used engine oil added to it gave the lowest values. Different researchers have reported differently on the effect of engine oil on the chemical properties of the soil. For instance, Kayode *et al.*, (2009), reported that pollution of vegetative soil with spent lubricating oil altered the physical and chemical properties of the soil. They further observed significant changes in the spectrum of nitrogen, phosphorus, magnesium, calcium and pH in lubricating oil polluted soil. Similar studies have also been reported by Ogiri *et al.*, (2001) and Gbaruko *et al.*, (2005).

Table 2: Effect of soil contamination with used engine oil on selected soil chemical properties

Treatments	pH (H_2O)	OC g/kg	OM g/kg	N g/kg	P mg/kg	K mmol/kg	Ca cmol/kg	Mg cmol/kg	EA mmol/100 g
E1	5.58a	10.00a	16.80a	0.57a	12.53e	0.32c	1.58b	0.82d	1.72d
E2	5.71ab	31.10b	57.37b	1.73b	7.17d	0.08b	1.41a	0.75c	1.65c
E3	5.67ab	34.80b	52.50b	1.63b	4.83c	0.06ab	1.43a	0.73bc	1.64bc
E4	6.18ab	35.40b	60.83b	1.90b	4.20bc	0.05ab	1.42a	0.73bc	1.61ab
E5	6.24b	35.50b	61.13b	1.83b	3.13ab	0.03a	1.44a	0.71ab	1.59a
E6	6.18ab	36.00b	61.90b	1.93b	2.53a	0.02a	1.40a	0.68a	1.58a
SE$\pm$	0.18	0.24	0.60	0.17	0.66	0.02	0.02	0.01	0.01

Means with the same letter(s) within the same column are not significantly different at 5 % level of significance.
E1= control soil without used engine oil contamination, E2=control soil from mechanic site, E3= 187.5mls, E4=375mls, E5=562.5mls, E6= 750mls used engine oil and SE = standard error

Effects of used engine oil contamination soil on microbial growth

Total Bacterial Count

The mean total bacterial counts of the soil samples ranged from 5.6×10^{-6} colony forming units (cfu) per gram of soil to 3.53×10^{-6} cfu/g of soil (Table 3). Although there were differences in the values, these differences were not statistically different from each other. The reduction in bacterial count of E4, E5, E6 and soil from mechanic village site treatments could be attributed to the death of the bacteria due to poor nutrient availability and/or the toxic nature of the used oil in the soil. These treatments might not have provided adequate food for the oil eating bacteria to the level that may favour their abundance. This is similar to the findings of Ismail *et al.*, (2008) who observed a noticeable greater decline of bacteria counts and diversity but a prevalence of the genus *Pseudomonas* over the other identified genera in freshly contaminated soils. This reduction in bacteria population is also in line with the findings of Stephen *et al.*, (2011, 2013) who observed higher viable bacteria count in non-oil contaminated soil than in the polluted soils.

This increase in bacterial population in treatment E3 (187.5 mls lowest volume of used engine oil) also indicates that the presence of spent oil either attracted hydrocarbon degrading organisms or served as substrate for the multiplication of some indigenous hydrocarbon degrading microbes especially when the volume added to the soil is not much. Udom (2008) and Jelena *et al.*, (2009) reported similar findings. Inference drawn from their result was that substantial adapted population of microorganisms exists in hydrocarbon contaminated zones with the bacterial biomass increasing as the organic contaminants are metabolized. Ahamefule (2013)) also observed that the presence of spent engine oil in the soil resulted in significant increase in microbial population and metabolic activities. Ahamefule (2013) further reported that the number of hydrocarbon-utilizing organisms were higher in oil polluted sites than in the unpolluted sites.

Total Fungal Counts

The mean total fungal counts (TFC) of soil samples ranged from 7.0×10^{-5} cfu/g of soil to 5.00×10^{-5} cfu/g. The highest counts were observed in soil of E3 (187.5mls) treatment, while lowest counts were observed in control soil from mechanic village site and E5 (562.5 mls) as shown in Table 3. There was an increase on fungal population in soils of E3 (187.5

Table 3: Effects of soil contamination with used engine oil on Bacterial and Fungal population

Treatments	Bacterial count cfu/ml)	Fungal count (cfu/ml)
E1	4.90	5.33
E2	3.53	5.00
E3	5.60	7.00
E4	4.10	6.67
E5	4.17	5.00
E6	4.30	5.67
SE$\pm$	0.96	0.94

E1= control soil without used engine oil contamination,
E2=control soil from mechanic site, E3= 187.5mls, E4=375mls,
E5=562.5mls, E6= 750mls used engine oil contamination, SE = standard error

mls), probably because of the low volume of used engine oil added to the soil; while the E2 treatment (control soil from mechanic site) and E5 (562.5 mls) gave the lowest fungal counts probably because of the long duration that the soil has remain contaminated or those soils had higher volumes of used engine oil added to them compared to the other treatments. However the differences in the mean values were statistically not different from each other.

The increase in fungal count probably indicates the presence of poly aromatic hydrocarbon (PAH) degrading fungi in the soil sample which are able to divide and proliferate quickly in the shortest possible period (Milala, 2015). This is similar to the findings of Stephen *et al.,* (2013), who discovered the predominance of crude oil degrading fungi *spp*. in polluted soils than in the unpolluted soils. Kuiper *et al.,* (2004), Okereke *et al.,* (2007), Nkweenleng *et al.,* (2008) and Chikere *et al.,* (2009) reported similar findings.

The degrading capabilities of oils revealed that the microorganisms isolated from the soil samples were able to degrade oil. The cells were able to multiply during the incubation periods, indicating that they were able to degrade and utilize the oils for their growth and development. All the organisms maximally utilized all the hydrocarbon substrates when supplied as the sole source of carbon and energy (Olukunle 2013).

CONCLUSION

The result of this work shows that the contamination of the soil with used engine oil at different rates significantly ($P < 0.05$) increased the soil pH, organic carbon, organic matter and Total nitrogen contents of the soil compared to the control treatment where used engine oil was not added. Also as the concentration of used engine oil increased there was a gradual increase of these parameters, even though there were no significant ($P > 0.05$) differences among the treatments. However there was a significant ($P > 0.05$) reduction in phosphorus, potassium, calcium and magnesium contents of soils contaminated with used engine oil compared to the control treatment where used engine oil was not added.

The results also showed that used engine oil polluted soils reduces the population of microbes especially the bacteria count in most treatments compared to the control where used engine oil was not added.

This is an indication that pollution of the environment with used engine oil accidentally or due to human activities can affect nutrient availability for crop uptake either positively or negatively. It also showed that this can enter the food chain and seriously affects animal and human health; distort the microbial population and consequently the soil chemical properties. Hence, there is need to enlighten the public against the danger posed by indiscriminate disposal of used engine oil in the environment.

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