Short-Term Remediative Impact of Spent Mushroom Substrate on Soil Nutrients in Spent Automobile Lubricant Habitat-Types at University Farm, University of Port Harcourt, Nigeria

Gbarakoro T. N.[1,*], Chukumati J.[2]

[1]Deartment of Animal and Environmental Biology, University of Port Harcourt, Nigeria
[2]Department of Crop and Soil Protection, Faculty of Agric, University of Port Harcourt, Nigeria

Abstract The remediation potentials of spent mushroom substrate *(Pleurotus astreatus)* (Oyster mushroom) was investigated on soils contaminated with spent automobile lubricant at University of Port Harcourt farm (Dec-Feb. 2015) to determine the available nutrients and concentration of total hydrocarbon content. Sixteen sub-plots were contaminated with 2-L and 4-L of spent automobile lubricant, and 4 sub-plots without any contamination (control). Eight of the contaminated plots; were treated (remediated) with 1.7kg of spent mushroom substrate, 14 days post-contamination. Soil samples were collected at 10cm depth from each habitat 14 days post-remediation and taken to the laboratory for analysis of organic nitrogen using calorimetric measurement by Brucine method, organic carbon by rapid titrimetric method. Total hydrocarbon content (THC) was measured by spectrophotometer and available phosphorus by the Bray's P method and potassium by Flame Atomic Absorption Spectrophotometer. Soil edaphic factors were also determined. Results obtained indicate that soil pH was 5.4 (2-L impacted), 6.11 (2-L remediated) habitat-types, and 6.06(control). Concentration of nitrogen was 0.089%, 0.16%, 0.15% in the impacted, remediated and control sites. Phosphorus and Potassium was 23.3mg/kg; 33.3mg/kg (impacted), 7.20mg/kg; 10.04mg/kg (remediated) and 46.2mg/kg; 12.0mg/kg (control) sites. Total hydrocarbon concentration (THC) was 3.9mg/kg (control), 12.1mg/kg (2-L impacted) and 4.8mg/kg (2-L amended) habitat-types. There was a significant difference in nutrient composition between the remediated and impacted habitat-types.

Keywords Remediation potentials, Mushroom Substrate, Spent Automobile-lubricant, Habitat-types, Nutrients, Spectrophotometer

1. Introduction

Soil is a complex mixture of weathered mineral materials from rocks, partially decomposed organic molecules, and a host of living organisms. Soil is an ecosystem and an essential component of the biosphere, which can be used sustainably, or even enhanced under careful management [1]. A healthy soil is composed of 50% mineral matter and 50% plant and animal residues, air, water and living organisms.

The mineral particles are derived either from the underlying bedrock or from materials transported and deposited by glaciers, rivers, ocean currents, windstorms or landslides; much of the organic material in soil is humus which coats mineral particles, and holds them together in loose crumbs, giving the soil a spongy texture that holds water and nutrients needed by plant roots. The new texture provides spaces for the growth of dedicate root hairs. Generally, soils are basis for agricultural production since it is the source of nutrient element needed for plant growth and provide anchorage for the plant.

Among the nutrient elements are the basic types such as nitrogen, phosphorus, potassium and organic carbon, including total organic matter. Other basic soil parameters includes, soil pH, moisture and temperature. Soils are often subjected to two forms of deterioration; chemical and physical. These could be by way of chemical-pollution (including oil spills), nutrient depletion, salinization and acidification. These form of deterioration especially those caused by spent auto mobile lubricant results in reduction of physico-chemical parameters of the soil.

Spent automobile lubricant which is a brown-to black liquid produced when new mineral-based crankcase oil is

subjected to high temperature and high mechanical strain [2] has been reported to reduce the pH of soil slightly, making the soil a little more acidic [3]. Similarly, [17] reported that soil polluted with heavy metals such as iron and copper showed acidic pH. Spent or used or waste automobile lubricant caused soil pollution because it contain a mixture of several different chemicals including hydrocarbons, decomposition products and heavy metal contaminants such as aluminum, chromium, lead, manganese, nickel and silicon that come from automobile parts as they wear down [5]), which enters the soil through two sources;

(a) When motor oil is changed and disposed into the soil by motor and generator mechanics, and small scale engine oil sellers along Nigerian roads [6].

(b) When release from exhaust system during engine use and due to engine leaks [7].

This illegal dumping of waste oil into the soil cause among others soil hardening and colour changes of soil [8], immobilization and alteration of availability of soil nutrients and lowering of Ph [9]. Nigeria accounts for more than 87 million litres of spent lubricants annually and attention has not been given to how it is been disposed [7].

It has been shown that soil temperature at spent automobile treated site was higher than that of untreated site [10].

Improvement of basic soil parameters including nutrients by spent mushroom substrate from hydrocarbon contaminated soils has been reported. Accordingly spent mushroom substrate; a composted organic material remaining, after a mushroom crop has been harvested improve the soil physico-chemical parameters [11] and reduce total petroleum hydrocarbon [12]. This substrate is highly rich in essential nutrients such as nitrogen, phosphorus and also contains micronutrients such as iron, manganese, copper and zinc in very low average between 0.01 and 0.2. It also contain salts such as sodium, calcium and magnesium, in which calcium and magnesium are always in larger amount than sodium and thus neutralizes sodium, preventing it from accumulating on the soil particles [13]. Spent mushroom substrate has been used as an organic soil amendment and fertilizer for crop production and other land management issues [14].

With these established background, the objective of the present study is to ascertain the impact of spent mushroom substrate applied as a remediating agent on the nutrient composition of soils contaminated with spent automobile lubricant.

2. Materials and Methods

Study Area/Design

The study was carried out at the University farm behind University of Port Harcourt water bottling company, University Park, University of Port Harcourt (4^0 54^1 33.ON 6^0 55^1 20.OE) from December to February, 2015.

Study Design

The study area was divided into 4 plots; each into 4 sub-plots measuring 2m x 1.5m with 1m distance separating the plots both vertically and horizontally. It was replicated in a completely randomized design; the 4 sub-plots are referred as replicates.

There are 5 treatments; zero, 2-litre, 4-litre, spent automobile lubricant, 2L+spent mushroom substrate and 4L+spent mushroom substrate.

The treatments were assigned randomly to the 4 plots and its replicates, giving a total of 20 sub-plots. The zero treatment plots were the control plot.

The sub-plots or replicates containing the same treatment were group together and referred to as habitat-type. Consequently there were 5 habitat-types. Twenty sub-plots covering $160m^2$ were engaged in this investigation. Sixteen of these sub-plots (4 plots) were contaminated with 2L and 4litres of spent automobile lubricant, and 4 sub-plots without any contamination.

14 days post-contamination, 8 of the contaminated plots; containing 2 and 4litres were treated with 1.7kg of spent mushroom substrate by mixing thoroughly with a trowel to ensure quick penetration. Soil sampling commenced 14 days post-remediation. The 5 treatments are referred to as habitat-types.

Determination of Basic Soil Parameters:

Soil samples were collected at 10cm depth from each habitat. The samples were thoroughly mixed together and put into a polythene bag and taken to the laboratory where they were air-dried at room temperature. From here it was used to analyse organic nutrients and Total hydrocarbon concentration. 20g of the composite samples were wrapped in foil papers and put in an oven for over 24hrs for drying. It was digested by grinding the soil samples into powder and sieved through 2mm mesh size to get fine particles. The particles were analysed for soil potassium.

Nutrients

The organic nitrogen was determined by calorimetric measurement using Brucine method [15]. Organic carbon was determined by rapid titrimetric method [16] and total organic matter was calculated by multiplying percentage organic carbon by 1.724. Available phosphorus (P), in the soil sample was determined by the Bray's P method. Exchangeable potassium (K) was extracted with 1N neutral ammonium acetate solution. Thereafter potassium (K) was determined by flame Atomic Absorption Spectrophotometer. Effective cation exchange capacity (ECEC) was calculated by the summation of all exchangeable bases and acids.

Measurement of Soil Total Hydrocarbon Content (THC)

Soil total hydrocarbon content (THC) was measured by spectrophotometer method without silica gel which involved an absorbance of liquid extract read at a wavelength of 425nm using xylene as blank sample. Finally, concentrations were extrapolated from a prepared calibrated curve against corresponding absorbance. Soil total THC was measured.

Determination of Basic Soil Parameters (Soil Edaphic Factors)

Measurement of Edaphic Factors

Soil Moisture Content:

50g of composite soil sample was collected from 0-10cm depth of each treatment plot and weighed with OHAUS portable scale scout II electrical weighing balance manufactured in China to determine soil moisture content. Samples were wrapped in Tower foil paper, labeled and placed in B and T laboratory Thermal Equipment (oven) manufactured in England for 24hrs.

$$\text{Soil moisture content } \% = \frac{loss\ in\ weight}{initial\ weight}\ x\ 100$$

Soil Temperature:

Soil temperature readings were taken by inserting the thermometer (Quick-fit mercury-in-glass) into the soil to a depth of 10cm for 5mins before taking the reading in degree Celsius (°C).

Soil pH:

20g of composite soil sample collected from each treatment plot was sun dried and placed in a 50ml beaker. 20ml of distilled water was added, stirred occasionally with a glass rod and allowed to stand for 30 minutes to determine the soil pH. The electrode of each Equip-Tronics digital pH meter (model EQ-610) was then inserted into the solution and pH readings recorded.

Statistical Analysis:

The data obtained in this study was subjected to analysis of variance, to ascertain the differences between treatments. Tukey HSD multiple comparisons test was used to analyze the effects of the treatments.

3. Results and Discussion

Improvement in basic soil parameters:

At the end of the study, an improvement in soil edaphic factors was recorded. There was an increase in soil temperature from 25.5°C to 26.2°C and 27°C from the uncontaminated to 2L and 4L – contaminated habitat-types. This increase is as a result of the effect of the spent automobile lubricant (Table 1).

Table 1. Mean Basic Soil Parameters at the Study Sites

Habitat-types	Temp (^{o}C)	pH	Moisture (%)
0 (control)	25.5	6.06	7.5
2L-impacted	26.2	5.4	10.1
4L-impacted	27	5.6	14.6
2L remediated	26	6.11	9.9
4L remediated	26.7	6.01	12.2

This result agrees will the report of [10] that spent automobile lubricant increase the temperature of the soil above the untreated sites. The increase though very slight may be due to the slight compactness of the soil at the contaminated habitat- types. This compactness may have heated up the soil to cause rise in temperature. At the remediated habitat-types, the spent mushroom substrate reduced the temperature to attaining that at the control (uncontaminated) habitat types. It is 26°C at 2L – substrate remediated and 25.5°C at the control habitat – types. The reduction in temperature was observed at the 4L – substrate habitat – types which recorded 26.7°C and 4L – contaminated habitat –types that recorded 27°C.

There was a reduction in the pH value at the contaminated habitat-types, making it acidic at 5.4 and 5.6. This reduction caused by the spent automobile lubricant was changed at the spent mushroom substrate habitat-types, it increased to 6.11 and 6.01 at the 2L – and 4L – substrate habitat-types respectively, and the spent mushroom substrate improved the pH value to such a level that there was no difference between the value at the control (6.06) and the remediated habitat-types (Table 1).

In the moisture content, the spent mushroom substrate reduced it to attain those of the control habitat-types. While that of the control was 7.5%, 2L contaminated was 10.1% and 2L remediated 9.9%. This indicates that spent automobile lubricant increased the moisture of the soil and was improved by reducing it to near normalcy by the spent mushroom substrate. This agrees with the report of [9] that spent automobile lubricant lowered the pH of the soil. A similar reduction was recorded at the 4L remediated habitat-types.

These observed improvements agree with the report that spent mushroom substrate as organic waste causes rapid improvement of soil physic-chemical parameters [11].

Increase in Soil Nutrients

This is another area where the impact of spent mushroom substrate was observed and recorded. Essential or basic soil elements such as nitrogen, phosphorus and potassium were lower in concentration in the contaminated habitat-types due to the severity of the spent automobile lubricant, than in the remediated habitat-types. It was 0.089%, 23.31mg/kg, 7.20mg/kg for nitrogen, phosphorus and potassium respectively at 2L-contaminated habitat-types. When this same habitat-types was remediated with spent mushroom substrate, an increase in the concentration of these basic soil nutrients was recorded. It increases from 0.089% to 0.16% for nitrogen, 23.3mg to 33.3mg/kg for phosphorus and 7.20mg/kg to 10.04mg/kg for potassium. This increase in availability of nutrients within 3 months explains the impact of spent mushroom substrate as organic waste in soils contaminated with spent automobile oil. In the control habitat-types, it was 0.15% nitrogen, 46.2mg/kg phosphorus and 12.0mg/kg potassium (Table 2).

Spent mushroom substrate is highly rich in nitrogen and phosphorus and has contributed immensely in the availability of these nutrients in the amended or remediated soils.

Table 2.   Concentration of Nutrients in Automobile Hydrocarbon Amended Habitat-Types during the period of Study

Habitat-types	THC (mg/kg)	TN (%)	TP (mg/kg)	TK (mg/kg)	Toc (%)	Tom (%)
0L control	3.9	0.15	46.2	12.0	1.7	3.0
2L impacted	12.1	0.09	23.3	7.2	3.0	5.1
4L-impacted	13.1	0.09	16.7	10.3	4.3	7.4
2L + SMS remediated	4.8	0.16	33.3	10.1	1.8	3.1
4L + SMS remediated	6.4	0.09	18.7	5.0	3.2	5.5

Increase Hydrocarbon-induced Total Organic Matter

Spent mushroom substrate caused a reduction in the total hydrocarbon content of the soil which was earlier increased by the spent automobile lubricant over those in the control. This reduction was much, such that after 10 weeks of post-remediation, it was 43.2% (7.3mg/kg) reduction in 2L-remediated habitat-types (Table 2). The spent mushroom substrate biostimulated the hydrocarbon degrading soil microorganisms including microarthropods by providing the required nutrients to biodegrade the spent automobile lubricant. This agrees with the report of [20] that such substrate contains nitrogen and phosphorus which are nutrients needed by hydrocarbon utilizing bacteria to carryout effective biodegradation in the soil. The roles of spent mushroom substrate in the reduction of total hydrocarbon content of soils contaminated with spent automobile lubricant has been reported [4], however, the positive effects of nitrogen amendment on microbial activity and/or petroleum hydrocarbon degradation has been reported [18, 19].

The concentration of total organic matter observed and recorded at the 2L and 4L concentrated habitat-types was hydrocarbon induced. This is because the spent automobile lubricant increased the soil carbon from 1.7% (control) to 2.98% and 4.31% in the 2L and 4L concentrated habitat-types respectively, which in turn increased the percentage of total organic matter (Table 2). The hydrocarbon induced high total organic matter caused more compactness of the soil in the contaminated habitat-types. This was reduced in the remediated habitat-types where spent mushroom substrate provided the required nutrients that stimulated the activities of degrading organisms to reduce the total hydrocarbon content of the soil and consequently a reduction in total organic matter tending towards those in the control. Total organic matter was 5.14% at 2L-contaminated habitat-types and 3.06% at 2L-remediated habitat-types while at the control it was 2.9%. A similar reduction in total organic matter was also observed in 4L-remediated habitat-types (Table 2).

The reduction in hydrocarbon-induced total organic matter also helps loosen the compactness of the soil at the remediated habitat-types. This will ensure mobility of the nutrients and it agrees with the report of [12] that total organic matter help loosen the compactness of the soil, making sufficient aeration for the microorganisms.

4. Conclusions

This study have pointed out that spent mushroom substrate applied as remediating substances have the capacity of reducing hydrocarbon-induced total organic matter and hydrocarbon pollution thereby improving basic soil parameters, mobilization of nutrients and ecological balancing of the ecosystem.

ACKNOWLEDGMENTS

REFERENCES

[1]   Cunning-ham, W.P. Cunningham, M.A. and Saigo, B.W. (2003). Environmental sciences; A global concern 7th Edn. The McGraw-Hill companies Inc. New York 646pp.

[2]   Ameh, A. O., Mohammed-dabo, I, A., Ibrahim, S., Ameh, J. B., Tanimu, Y. and Bello, T. K. (2012). Effect of earthworm inoculation on the bioremediation of used engine oil contaminated soil. *International Journal of Biological and Chemical Sciences*, (1): 493 – 503

[3]   Olla N.O., Adejuyigbe C.O. and Bello W.B. (2013). Ameliorative Effects of Organic Manures on soil P[h] Organic Carbon and Microarthropod Pollution. *American-Eurasian J. Agric & Enivron. Sci,* 13(11): 1541-1546, 2013

[4]   Gbarakoro T.N., Oneche, E and Umeozor, O.C. (2015). Impact of Heavy Metals on Species Richness, Abundance and Vertical Distribution of soil microarthropods in Waste Dump Sites at Delta Steel Company, Warri, Nigeria. International Journal of Environmental & Resource. Vol. 4; (9-15).

[5]   Wang, J., Jia C.R., Wong, C.K. & Wong, P.K. (2000). Characterization of polycyclic aromatic hydrocarbon created in lubricating oils. Water, air, soil pollution: 20(3-4), 381-396.

[6]   Odjegba, V. J.and Sadiq, A. O (2002). Effect of Spent Engine Oil on the Growth Parameters, Chlorophyll and Protein levels of *Amaranthus hybridus* L. The *E nvionmentalist*, 22: 23-28.

[7]   Osubor, C. C. and Anoliefo, G. O. (2003). Inhibitory effect of spent lubricating oil on the growth and respiratory function of *Arachis hypogaea* L. *Benin Science Dig*. 1: 73 – 79.

[8]   Udeani, T. K. C., Obroh, A. A., Okwuosa, C. N., Achukwu, P. U. and Azubike, N. (2009). Isolation of bacteria from mechanic workshops soil environment contaminated with used engine oil. *African Journal of Biotechnology*, 8(22): 6301 – 6303.

[9]   Atuanya, E. I. (1987). Effect of waste engine oil pollution on the physical and chemical properties of the soil. A case study of waste oil contaminated Delta soil Bendel State, Nigeria. *Appl. Sci.* 5: 155-176.

[10] Rotimi, J. and Ekperusi, O.A. (2014). Effect of spent lubricating oil on the composition and Abundance of Arthropod Communities of an urban soil. Journal of Applied Sciences, Environmental Management. Vol. 18(3): 411-416.

[11] Jorgensen, K. S., Puustinen, J. and Suortti, A. M. (2000). "Bioremediation of petroleum hydrocarbon contaminated soil by composting in biopiles," *Environmental Pollution,* vol. 107(2): 245-254.

[12] Abioye, O. P., Agamuthu, P., and Abdul, A. (2012). "Bioremediation of Used Motor Oil in Soil Using Organic Waste Amendments," *Biotechnology Research International.* vol. 8(2): pp. 56- 67.

[13] Mike F. and David B. (2013). Plant nutrient and fresh mushroom compost. Prentice Hall, Upper Saddle River, NJ.

[14] Brady, N.C. and Wal, R.R. (2000). Elements of Nature and Properties of Soil. Prentice Hall, Upper Saddle River, NJ.

[15] Odu CTI, Babalola O, Udo EJ, Ogunkule AO, Bakere TA, Adeoye GO (1986). Laboratory Manual for Agronomic studies in soil, plant and microbiology. University of Ibadan, Ibadan Press Ltd p. 83.

[16] Osuji L.C. and Adesiyan S.O. (2005). "Extractable hydrocarbons, nickel and vanadium contents of Ogbodo-Isiokpo oil spill polluted soils in Niger Delta, Nigeria." Environ Mont. Access 2005 Nov; 110 (1-3):129-39.

[17] Gbarakoro T.N. and Chukumati, J. (2016). Impact of Spent Mushroom substrate on soil microarthropods in Spent Automobile Lubricant Habitat-types at University Farm, University of Port Harcourt, Rivers State, Nigeria. International Journal of Environment and Pollution Research. Vol. 4(4); 13-23.

[18] Margesin R, Hammerle, M & Tscherko D. (2007). Microbial activity and community composition during bioremediation of diesel − oil contaminated soil: effects of hydrocarbon concentration, fertilizers and incubation time "microbial ecology, Vol. 53 (2): 259-269.

[19] Riffaldi, R., Levi-Minzi, R, Cardelli, R., Palumbo, S., and Saviozzi, A. (2006). "Soil Biological Activities in Monitoring the Bioremediation of Diesel Oil-Contaminated Soil", Vol. 170, Issue 1–4, pp 3–15.

[20] Okoh I.O. (2006). Biodegradation alternative in the cleanup of petroleum hydrocarbon pollutants, Biotechnology and Molecular Biology Reviews, vol. 1, no. 2, pp. 38-50.