ISSN: 2695-2556 (Online)
ISSN: 2651-5679 (Print)

AKSU Journal of Agriculture and Food Sciences 7(2) 89-101

Effect of Used Lubricant Oil on Soil Physicochemical Properties in Auto-mechanic Workshops Uyo, Akwa Ibom State

[1]Itoro David J. Udoumoh, [2]John D. Umoh, [1]Itakufok G. Uduak, [1]Okon E. Udoh and [3]Sekerema U. Silas and [1]Nsikan E. Idiong

[1]Department of Soil Science, Faculty of Agriculture, Akwa Ibom State University, Nigeria
[2]Department of Environmental Toxicology, College of Natural Resources and Environmental Management, Michael Okpara University of Agriculture, Umudike, Nigeria
[3]Department of Soil and Land Resources Management, Faculty of Agriculture, University of Uyo, Uyo, Nigeria

Correspondence Author's Email: *itoroudoumoh@aksu.edu.ng*

Abstract

The effects of used lubricated oil (ULO) on soils from some auto mechanic workshops in the Uyo urban of Akwa Ibom State were investigated to assess their influence on some soil physical and chemical properties. The stratified random sampling method was employed to select four automobile workshops through which sixteen (16) soil samples from each were collected and analyzed. The outcome of the study showed that there were significant differences in soil properties of the contaminated soils with those of the control, with variations seen majorly among the soil characteristics of the two sampling points (ULD 1 and 2). Correlations, between pH and electrical conductivity ($p< 0.01$; $r =0.0667$) were significant. The gravimetric moisture content correlated negatively with total porosity ($p< 0.05$; $r = - 0.2857$) and organic carbon ($p< 0.05$; $r = - 0.3640$). Base saturation correlated positively with effective cation exchange capacity ($p< 0.05$; $r = 0.5832$). Results further revealed that used lubricant oil changes the soil properties and may negatively affect sensitive bacteria. Excluding properties such as particle size distribution, pH, temperature and nitrogen, all other properties of the soil from the study areas were considerably different from those of the control sites. This contamination considerably changed most of the soil properties and may adversely influence microbial diversity of the area. The application of organic manure will help to improve soil fertility by supplying the deficient nutrients.

Keyword: Used lubricant oil, Physicochemical properties, Soil quality

1.0 Introduction

Soil is a non-renewable natural resource obtained from nature by man. It is an energetic living structure which carry out major agricultural and environmental functions; consisting of diversities of both micro and macro fauna/flora which perform important roles in sustaining soil quality (Alabi *et al.,* 2019; Sultan *et al*, 2015). It's comprises of several mineral nutrients, organic matter, water, air and living organisms established through numerous factors such as climate, parent material, relief and time factor (Blott *et al.*, 2012). Bassey *et al.*, (2019) defines soil as a resource whose condition ultimately affects the well-being of everything that depends on it directly or indirectly. Activities in the soil adversely affect other domains of the environment vis-à-vis the air (atmosphere), water (hydrosphere) and soil itself which is an offshoot of the lithosphere. Used lubricant oil (ULO) also known as waste engine oil (or condemned oil and or spent engine oil) refers to any lubricant that has served its primary functions in vehicles such as tricycles, motorcycles, motor, generators, etc. and has been removed from its area of application after considering it unfit for the vehicles' continuous use (Abioye *et al.*, 2012). It is obtained from automobile mechanic and or electrical engine repairers' shops after being used by vehicles, generating set and other types of engines (Anoliefo and Vuioko, 2001). ULO has dark brownish to blackish colour and is hostile to man and the soil environment (Adedokun and Ataga 2007). It comprises of a combination of several chemicals including low to high molecular weight compounds (C_{15}-C_{21}), lubricants, additives, decomposition products and heavy metals which have been confirmed to be unfavourable to human health and soil (Daffus, 2002). The works of Ekudayo and Obuekwe (2020) shows that significant changes occur in soils microbial and physicochemical properties contaminated with ULO. The presence of oil replaces air and water; creating an anaerobic condition in the soil (Chukwuma *et al.,* 2010; Atlas, 1977).

Ikpe (2023) noted that unwholesome release of ULO into the environment is one of the most significant causes of environmental degradation leading to the loss of soil quality thereby reducing the soil microbial biodiversity. These distorts the soil quality both on local and on a large-scale scale with the degradation hindering economic growth and vital environmental functions. Soil quality comprises of both biological and physicochemical properties of soil and is depended on the soil nutrient pools, which are modulated by land use and a number of other land management factors (Subnin *et al*., 2015; Byrne *et al*., 2021). ULO contamination of soil according to Odjegba and Sadiq(2012) causes the soil to lose all its valuable properties including soil fertility, water holding capacity, permeability and binding capacity. The activities, numbers and diversity of soil microbes which serves as indicators of a fertile soil are always altered by contaminants such as ULO (Udoumoh *et al., 2019*). These alterations distress the economic productivity of farmers locally and influences soil quality on a global scale. Soil quality according to Subnin *et al* (2015) includes biological and physicochemical properties of the soil (and these are influenced by land use and other land management systems). Various types of industrial and agricultural activities occur in urban centres with resultant municipal waste (Onwuka, *et al* 2012). These wastes (including ULO) can be recycled or converted to other productive use.

ULO contain several toxic substances which are injurious to the ecosystem, which in turn affect the growth, yield and general wellbeing of plants and animals in an area (Atunnya, 1987). There is a growing concern that indiscriminate disposal of ULO may cause harmful effect to humans. Hence, this work was to establish the consequence of ULO on some soil physicochemical properties in certain auto-mechanic workshops in Uyo urban of Akwa Ibom State, Nigeria. The specific objectives were: (i) to ascertain the effect of ULO on the physicochemical properties of the studied soil (ii) to ascertain the relationship between ULO and soil physical properties.

2.0 Materials and Methods

2.1 Experimental Site Description and Sample Collection

The soil samples used in this study were collected from four (4) different automobile mechanic workshops within Uyo. Uyo is the Capital City of Akwa Ibom State and located between latitudes 4°58'N and 5°04'N and longitudes 7°51'E and 8°01'E. The different locations in Uyo were AtanOffot, AfahaOffot, IbokoOffot, and EffiatOffot. Two sampling points were mapped out around each auto-mechanic workshop. The reference points (1) were at the point of release of the used lubricant oil (ULO) into the soil which was referred to in this study as the used lubricant dumpsite (ULD). Points (2) were uncontaminated agricultural land about 500 m away from the reference point. These served as the controls. Based on the works of Iren and Ediene (2017), composite samples were collected at each sampling point at the depths of 0–15 cm (topsoil) and 15-30 cm (subsoil) using a soil auger. Sixteen (16) composite samples were collected from the four (4) different auto-mechanic workshops. The samples collected were air-dried, crushed and passed through a 2 mm sieve to eliminate materials greater than 2 mm in diameter and subsequently transferred into polythene bags, and properly labelled.

2.2 Laboratory Analysis

Particle size analysis was conducted using the Bouyoucos (1951) hydrometer method as described by Udo *et al.*, (2009). A textural triangle was used to establish the soil textural class after dispersing the soil particles with sodium-hexametaphosphate solution. The bulk density was determined by the method described by Dane and Topp (2002). The soil samples were oven-dried at 105^0C to a constant mass, out of which the bulk density was calculated using the equation below:

$\ell b = Ms/Vt$ ……………………………………………………………………..Equation 2.1

Where:

ℓ_b = bulk density (Mg m^{-3}), M_s= Mass of oven dry soil (kg), and V_t = total volume of soil, (m^3).

The total volume of soil was calculated from the inner dimensions of the cylinder. The total porosity was calculated from the values of the particle and bulk density relationship as follows:

$F = [1-(\ell b/\ell s)]$ ………………………………………………………………..Equation 2.2

Where:

F = total porosity (m^3/m^3), ℓ_b= bulk density (Mg/m^3), and ℓ_s = particle density (Mg/m^3).

Macro porosity was calculated from the values of total porosity and field water capacity of the soil as follows:

$fa = ft - \Theta v$……………………………………………………………........…….Equation 2.3

Where:

f_a = macroporosity (m^3m^{-3}), f_t = total porosity (m^3m^{-3}) and Θ_v = volume of water held at field capacity (m^3/m^3)

Soil pH was determined in water and in KCl using 1:2.5 soils to water suspension and the pH value was read using a glass electrode pH meter as used by Onwudike (2015). Electrical conductivity was determined using a conductivity bridge as described by Udo *et al.*, (2009). Organic carbon was determined by the dichromate wet oxidation method of Walkey and Black as described by Nelson and Summer (1996). Total nitrogen was established by the Kjeldahl digestion and distillation method as described by Udo *et al.*, (2009). Bray P_1 method was used to establish available phosphorus. The phosphorus in the extract was intended by the blue method of Murphy and Riley (1962). Exchangeable bases (Ca, Mg, Na and K) were infused using standard ammonium acetate (IN NH_4OAC) solution (Thomas, 1982). The exchangeable K and Na were established by flame photometer by atomic absorption spectrophotometer.

2.3 Statistical Analysis

Descriptive statistics was used to study the variables across the various sampling locations. Mean served as a primary estimate of central tendency while minimum, maximum and standard deviation (SD) served as estimates of variability of the soil characteristic. Spearman's correlation was used to establish the correlation between used lubricants oil and soil properties.

The data were also subjected to analysis of variance (ANOVA). The treatment means were separated for the significant difference using the Fishers Least Significant Difference (LSD) at a 5% probability level.

3.0 Results and Discussion

3.1 Effect of Used Lubricant Oil on Soil Properties

From table 3.1, the particle size distribution shows that soils polluted with ULO were pigeonholed with moderately high sand content ranging from 72.86 - 78.76 % for 0 -15cm depth, and 80.76 - 86.76% for 15-30cm depth, and an average (± SD) of 80.153 ± 1.606 %; silt 3.30-7.48 % for 0-15cm depth, 3.42-7.48% or 15-30cm depth (mean ± SD) of 5.23 ± 1.046 % and clay 17.94-16.98 % for 0-15cm depth, and 9.80-16.98 for15-30cm depth(mean ± SD) of 15.10± 1.36 %. The ranges and mean of particle size distribution for the control samples were: sand 0-15cm: 74.80-82.82%, 15-30cm: 74.82-82.88% (80.33±1.24%); silt 0-15cm: 3.36-4.66%, 15-30cm: 1.56-3.98%. The textural designations of soils from the area were predominantly loamy sand. Soil samples from Atan (15-30cm) and EffiatOffot (15-30cm) were of varying texture; sand. The control sample from AfahaOffot (15-30cm) also showed varying textural designation (sandy loam), while the remaining soils showed uniform textural classes.

3.2 Effect of Used Lubricant on Soil Chemical Properties

The descriptive statistics results of physicochemical characteristics of the soils from the study area are shown in Table 3.2. The pH of the soils studied was acidic, with an average of 6.04 ± 0.34. Soils from control samples had the lowest pH mean value of 4.40 whereas soils from the ULO site had the highest pH of 6.40. The pH of soils under investigation was somewhat lower than the levels claimed by Bassey *et al (2019)* in the same region. In other parts of the Niger Delta Region of Nigeria, it was established to be higher in some hydrocarbon populated soils (Udeh, *et al* 2016). At Eluama in Abia State, Ezeigbo *et al*., (2013) reported that the pH was 4.5 while Olson *et al*., (2017) reported that it was 6.5 at Bomuin, in Gokana local government area of Rivers State. The pH levels corroborates with the result obtained by Wang *et al.*,(2013) from some polluted areas in Momoge Wetland of China. Previous study by Kisic *et al*., (2009), shows that the lowering of the soil pH can be caused by increase in total petroleum hydrocarbon, adding that there was no significant effect on soil pH as a result of increase in soil pH and hydrocarbon concentration in the soil sample. The acidity of the soils shows that the build-up of metals by cation exchange was negligible and metal build up was primarily due to adsorption of soil organic matter (Jia *et al*., 2009).

Electrical conductivity (EC) ranged from.03-0.170dSm^{-1} both in the ULO dump site and control samples with mean values of 0.12dSm^{-1}. These values were lower than 2dSm-1 and can be critical for crop production (Shannon, 1999). Available phosphorus ranged from 48.70gkg^{-1}-80.71gkg^{-1} in used dumpsites with mean values of 68.78gkg^{-1} while the control test samples ranged from 46.28-74.04gkg^{-1}. The mean value was higher than the critical value of available phosphorus for optimal crop production. The organic carbon for the ULO polluted site and control samples were1.10±0.35 and 1.50±0.30 correspondingly. The increase in the organic carbon contents in the soils from the automobile mechanical shops could be related to the input from hydrocarbon in the ULO as reported by Abosede (2013). The raise in the soil carbon content of the polluted sites is expected to harmfully affect the pace of degradation of organic matter by microorganisms. Organic matter ranged was 0.90-2.58gkg^{-1} for the soils in the contaminated sites and 0.90-2.58 gkg^{-1} for the controlled samples. This fortifies aggregation and aggregates protect organic matter from microbial disintegration, and development; Bronick and Lal (2005) attributed the poor state of aggregation in soils with respect to the time and deterioration rate of soil organic matter under favourable moisture and temperature conditions. Schnecker *et al*., (2014) reported that soil microorganisms amass organic carbon and nitrogen from organic matter, and this influences soil microbial community**.**

The sample from the control site contains the least nitrate while the sample from the polluted sites had the highest nitrate concentration. The total nitrogen concentration was 0.05±0.02cmol/kg for the polluted site and 0.04±0.01 for the control samples. In general, the phosphates and nitrate levels in soils from the ULO polluted sites were higher than those of the control sites, suggesting that there had been phosphates and nitrate build-up in the soil from the ULO. Nitrogen and phosphate are known products from crude oil. This according to Bai *et al.,* (2012) impacts the soil nutrient and bacteria diversity. Soil microorganisms are sustained by the presence of carbon and nitrogen in the soil. The carbon: nitrogen ratio of soils in the study sites are likely to be distorted by ULO contamination. This according to Pattnaik and Reddy (2009) could change the ability/decomposition rate of soil bacteria to degrade materials.

Moreover, Effective Cation Exchange Capacity (ECEC) of the soils in ULO contaminated site ranged from 6.31-9.74cmol/kg with an average of 8.31±1.15cmol/kg, while the control test samples ranges from 6.54 to 8.09cmol/kg with an average of 7.66±0.58cmol/kg. The ECEC result was medium (Udo*et al.,* 2009) and there was moderate variability in the results. Base saturation of the contaminated sites ranged from 65 to 74.4% with an average of 69.80%, and 65.70-70.60% with an average of 67.05% for the control. Base saturation was modestly different in the results.

The bulk density of soils from the contaminated sites ranged from 1.05 to 1.37 with an averageof 1.20±0.10 g/cm^3. There were higher than those of the control sites that ranged from 1.12 to 1.26 with an average of 1.17±0.05 g/cm^3**.** The reduction in porosity seen from the soils reflects the increase in bulk density. The bulk density was fairly normal contrary to the report by Kayode *et al.*(2009) who observed an increase in the soil polluted with ULO. This raise in bulk density of ULO polluted soil with a correspondent decrease in porosity could lead to soil compaction following the contamination. However, the bulk density values were not higher than the vital limits for soil productivity. This may be due to overflow by rainfall (Odiete *et al., 2005*). This hinders root penetration and also decreases air and water permeability with a likely adverse effect on the survival of microorganisms (Pathak *et al.,* 2011).Higher bulk density can be ascribed to compaction and deterioration of soil structure (Igwe, 2001). The bulk density is a parameter that significantly influences soil processes including water retention and fluid flow and has widely been used in the prediction of water transmission. Esu (2010) reports that bulk density above 1.60 Mg/ m^3 may indicate that water and aeration movement are too slow for optimum plant growth.

The total porosity of the polluted sites ranged from 0.48-0.60 with a mean of 0.55±0.04m^3/m^3 and 0.52-0.58 in the control site with a mean of 0.56±0.02 m^3/m (Table 3.3)**.** The lower porosity in the polluted soil implies that ULO in the soils have compressed the soil particles simultaneously, thereby diminishing the soil porosity, and altering the quality of soil structure. Porosity determines the extent to which water and air infiltration can occur in the soil (Ndimele *et al*., 2018). Parlak and Parlak (2011) observed that soil compaction is a basic ecological concern that results insubstantial degradation of the soil by adversely altering the hydraulic properties and productive parameters of the soil. Adding that it affects root growth and nutrient uptake. The soils from the polluted sites were dominated by reasonably low gravimetric water content, which ranged from 0.13-0.38 with an average of 0.21±0.08%and 0.22-0.50 in the control with an average of 0.29±0.08 (Table 3.3). Soils from the control sites generally have higher water content than those at the ULO sites. This report corroborates with the works of Wang *et al*., (2013). Petroleum hydrocarbon fill up the soil pores and reduces the soil surface water permeability thereby causing low moisture contents of the soils according to Khamehchiyan *et al.,* (2007). The mean diameter weight wet was used as an index for measuring aggregate stability. The average weight diameter of ULO polluted sites ranged from 1.10±1.62-1.29±0.15. Low mean weight diameter observed could be due to harmful impacts of ULO on other physical properties of soil such as bulk density, total porosity and water characteristics as seen from Table (3.3). Similarly, significant decrease in base Saturation (BS) was recorded by Nkwoada *et al*., (2018). Low stabilization of soil can hinder nutrients adsorption/release and increases its vulnerability to breaking up forces and moisture stress according to Abosede (2013). Disaggregation in stability may occur between the fallow and cultivated treatments which probably may be due to organic matter losses from soil disturbance (Udoumoh, *et al*., 2019).

The significance of relations amongst the physicochemical parameters of the soils analysed from the selected automobile workshops was determined using regression analysis and Spearman's Correlations. Bulk density showed significant and moderately negative relationship with total porosity ($p< 0.05$; r = - 1). Main useful correlations were noticed between pH and electrical conductivity ($p< 0.01$; r =0.0667). The gravimetric moisture content related harmfully with total porosity ($p< 0.05$; r = - 0.2857) and organic carbon ($p< 0.05$; r = - 0.3640). Base saturation had a positive correlation with ECEC ($p< 0.05$; r = 0.5832)'

4.0 Conclusion and Recommendation

The average particle size distribution followed the order: sand 78.53 ±5.80; Silt >15.10 ±1.89; and Clay >15.10 ±1.36. The distributions for the control samples follow a similar model. The particle size distribution of the study sites were not significantly altered from those of their control sites ($p<0.05$). Soils characteristics from the ULO sites were significantly different from soils of the control site, with much variation noticed between most of the soil characteristics. Noteworthy positive correlations were seen between pH and electrical conductivity. The gravimetric moisture content correlated detrimentally with total porosity and organic carbon. Base saturation had a helpful relationship with effective cation exchange capacity.

The study confirmed that used lubricant oil (ULO) distorts soil properties and may harmfully have effect on responsive microbial biota. Other properties of soils from the auto-mechanic shops were considerably different from the control sites, excluding particle size distribution, pH, temperature and nitrogen.

Table 3.1: Effect of used lubricant oil (ULO) on soil texture

Dumpsite Sample						Control Site					
Sample Location	**Depth (cm)**	**Sand%**	**Silt%**	**Clay%**	**Textural Class**	**Sample Location**	**Depth (cm)**	**Sand%**	**Silt%**	**Clay %**	**Textural Class**
AtanOffot	0-15	78.76	3.30	17.94	Loamy sand	Atan Offot	0-15	74.80	4.66	12.36	Loamy sand
	15-30	86.76	3.42	9.82	Sand		15-30	74.82	3.98	13.70	Loamy sand
AfahaOffot	15-15	76.82	7.48	15.17	Loamy sand	Afaha Offot	0-15	80.84	3.48	15.70	Sand
	15-30	80.76	6.42	12.82	Loamy sand		15-30	80.78	1.56	17.00	Sand
EffiatOffot	0-15	72.86	7.34	16.98	Loamy sand	Effiat Offot	0-15	82.81	3.36	13.20	Loamy sand
	15-30	84.96	3.44	9.80	Sand		15-30	82.86	2.14	14.00	Loamy
Mean		80.153	5.23	13.755				79.485	9.863	85.96	
Standard deviation		1.606	1.046	2.751				1.587	1.976	1.712	

Table 3. 2: Descriptive Statistics of Some Chemical Properties of the Control sites (C) and Used lubricants dumpsites (ULD) of soils in selected automobile workshops in Uyo Metropolis

Parameters	**Minimum**		**Maximum**		**Mean**		**Std. Deviation**	
	C	ULD	C	ULD	C	ULD	C	ULD
Ph	4.40	5.30	5.30	6.40	4.71	6.04	0.33	0.35
EC (ds/m)	0.09	0.09	0.17	0.17	0.12	0.12	0.03	0.03
Av. P(gkg-1)	46.28	48.70	74.04	80.71	65.05	68.78	11.47	11.06
OC (gkg-1)	0.88	0.52	1.77	1.48	1.50	1.10	0.30	0.35
OM (gkg-1)	0.90	0.90	2.58	2.58	1.92	1.92	0.61	0.61
Na (cmol/kg)	0.05	0.03	0.24	0.44	0.09	0.20	0.06	0.14
K (cmol/kg)	1.30	1.24	2.24	2.90	1.99	2.19	0.33	0.66
Ca (cmol/kg)	2.62	2.52	3.50	4.16	3.08	3.47	0.26	0.56
Mg (cmol/kg)	0.01	0.02	0.03	0.03	0.15	0.03	0.00	0.00
EA(cmol/kg)	2.38	2.08	2.80	3.20	2.64	2.41	0.14	0.35
TN(cmol/kg)	0.02	0.02	0.05	0.06	0.04	0.05	0.01	0.02
ECEC(cmol/kg)	6.54	6.31	8.09	9.74	7.66	8.31	0.58	1.15
BS (%)	65.70	65.0	70.60	74.40	67.05	69.80	1.56	2.95

C=Control site, ULD=used lubricant dumpsite, EC- electrical conductivity, Av.P- available phosphorus, OC – Organic carbon, Ca- calcium, Mg- Magnesium, Na- Sodium, K- Potassium, EA- exchangeable acidity, BS- base saturation, ECEC- Effective Cation Exchange Capacity and TN- Total Nitrogen.

Table 3.3 Descriptive statistics of some soil physical properties of the control(C) and used lubricants dumpsites (ULD) in selected automobile workshops in Uyo Metropolis

Parameters	Minimum		Maximum		Mean		S.D	
	C	ULD	C	ULD	C	ULD	C	ULD
B Density Mg/m3	1.12	1.05	1.26	1.37	1.17	1.20	0.05	0.10
Total Porosity m3/m3	0.52	0.48	0.58	0.60	0.56	0.55	0.02	0.04
Gravimetric Moisture content	0.22	0.13	0.50	0.38	0.29	0.21	0.08	0.08
Mean Weight Diameter Wet	1.03	1.10	1.62	1.57	1.30	1.29	0.16	0.15

C=Control site, ULD=used lubricant dumpsite

The product of the contamination was mostly likely the toxicity of the soil, which significantly distorted all the soil properties and the carbon: nitrogen ratio. Organic manure should be added to contaminated areas/sites and the contaminated plots should be allowed to stay fallow for a long period. This will improve the soil properties and restore the fertility status of the used lubricant oil (ULO) contaminated soils.

References

Abioye O. P., Agamuthu P. And Abdul-Aziz A. R. (2012): Biodegradation of Used Motor Oil in Soil Using Organic Waste Amendments. *Biotechnology Resource Institute,* doi: 10.1155/2012/587041.

Abosede, E. E (2013).Effect of Crude Oil Pollution on Some Soil Physical Properties. *IOSR Journal of Agriculture & Veterinary Science* 6(3): 14 - 17.

Adedokun O. M, Ataga AE (2007). Effect of amendment and bio-augmentation of soil polluted with crude oil automotive gasoline and spent engine oil on the growth of cowpea (*Vigna unguiculata L. walp*). *Scientific Research* 2(5):1147

Agbogidi, O. M. (2011). Effect of crude oil contaminated soil with spent engine oil in *Jatropha curcas* L., seedlings. *Journal of Ornamental and Horticulture Plants* 1(1): 39-45. 1149.

Alabi, A. B., Ayesanmi, A. F. and Olollade, I A. (2019)"Quantitative and Qualitative Assessment of Hydrocarbons in Soik Profiles of Auto-Mechanic Workshop: A Case Study of Akure City, Nigeria" *Polycyclic Aromatic Compounds* 2019

Anoliefo G .O. and Vwioko, D .E (1995). Effects of Spent Lubricating oil on the Growth of *Capsicum annum* L. and *Lycopersicon esculentum* Miller. *Environmental Pollution*, 88: 361-364.

Anoliefo G O, and Vwioko D. E (2001). Tolerance of *Chromolema odorota* (L.) K and R Grown In Soil Contaminated With Spent Lubricant *J. crop Biosci*. 1:20-24

Anoliefo, G. O. and Edegbai, B. O. (2000). Effect of Spent Engine Oil as a Soil Contaminant On The Growth of Two Egg Plant Species, *Solanum melongena* (L.) and *S. incanum* (L.). *Journal of Agriculture, Forestry and Fisheries*, 1: 21-25.

Atlas R. M (1977). Stimulated Petroleum Biodegradation. *Critical Reviews in Microbiology*. 5:371-386.

ATSDR (Agency for Toxic Substances and Disease Registry) (1997).*Toxicology Profile for Used Mineral Based* Crankcase Oil. Department of Health and Human Services, Public Health Service Press, Atlanta, GA, USA. pp. 1-208.

Atuanya, E. I (1987). Effect of Waste Engine Oil Pollution on Physical and Chemical Properties of Soil. A Case Study of Waste Oil Contaminated Delta Soil in Bendel State. *Nigeria Journal of Applied Sciences*, 5:155-176.

Bassey, D. E., Udoh, D. J. and Udoumoh, I. D. J. (2019).The Effect of Soil Management Practices on Some Soil Physical, Chemical Properties and Microbial Biomass in Abak Usung Idim, Akwa Ibom State, Nigeria. *AKSU Journal Of Agriculture And Food Sciences* vol (2) ISSN:2651-5679

Bai, J. H., Wang, Q. G., and Deng, W., (2012). Spatial and Seasonal Distribution of Nitrogen in Marsh Soils of a Typical Floodplain Wetland In Northeast China. *Environmental Monitoring and Assessment*, 184(3): 1253–1263. doi: 10.1007/s10661-011- 2037-3.

Blott S. J. and Pye K, (2012) Particle Size Scales and Classification of Sediment Types Based On Particle Size Distributions: Review and Recommended Procedures, *Sedimentology*, 59, 2071-2096.

Bouyoucous, G J (1951).A Recalibration of the hydrometer method for making mechanical analysis of soils. *Agronomy Journal*, 4:434- 438.

Bronick, C. J. and Lal, R. (2005) Soil Structure and Management: A Review. *Geoderma*, 124, 3-22.

Byrne, K. A., Efretuei, A., Walz, K., & Clay, G. D. (2021). Characterization of elemental ratios and oxidative ratio of horticultural peat. *Soil Use and Management*, *37*(3), 640-647.

Chukwuma, N. C, Eshett, E. T., Onweremadu, E. U. and Okon, M. A. (2010)."Zinc Availability in Relation to Selected Soil Properties in a Crude Oil Polluted EutricTropofluvent", *International Journal of Environmental Science & Technology*

Dane, J. H. and Topp, G. C. (2002).Methods of Soil Analyses Part 4, Physical Methods.*Soil Science Society of America Book Series*, pp 981-983.

Duffus J. H (2002). Heavy Metals “a Meaningless Term” (IUPAC Technical Report). *Pure and Applied Chemistry* **74**:793-807.

Ekundayo E. and Obuekwe O, (2000). Effects of an Oil Spill on Soil Physicochemical Properties of a Spill Site in a Typical Underpavement of the Niger Delta Basin of Nigeria. *Environmental Monitoring and Assessment*, **60**(2): 235–249. doi: 10.1023/A:1006 230025095

Esu, I. E., (2010). *Detailed soil survey of NIHORT farm at Bunkure Kano State, Nigeria.* Institute for Agricultural Research Samaru, Zaria, Nigeria.

Ezeigbo, O. R., Okike-Osisiogu, F. U., Ihemanma, C. N. and Agomoh, N. G. (2013). Microbiological Effects of Gas Flaring on Agricultural Soil at Izombe Flow-station, Imo State, Nigeria. *Journal of Biology, Agriculture and Healthcare,* 3(15): 96-100.

Ezeigbo, O. R; Ukpabi, C. F; Abel-Anyebe, O; Okike- Osisiogu, F. U., Ike-Amadi, C. A. And Agomoh, N. G (2013). Physicochemical Properties of Soil Contaminated with Refined Petroleum Oil in Eluama Community, Abia State, Nigeria. *International Journal of Scientific Research and Management* (IJSRM). 1(8) 405-413.

Igwe, C.A., (2001). Free Oxide Distribution in Niger Flood Plain Soils in Relation to their Total and Available Phosphorus. *Proceedings of the 27th Annual Conference of the Soil Science Society of Nigeria,* (SSSN'01), IEEE Xplore, London, pp: 196-201

IITA (1979). Selected Methods for Soil and Plant Analysis. *IITA Manual Series* No 1. Ibadan, Nigeria: IITA.

Iren, O. B. and Ediene, V. F., (2017) Effect of Spent Engine Oil Discharge on Soil Properties in Selected Automobile Workshop in Calabar, Cross River State, Nigeria - *International Journal of Innovative Science, Engineering & Technology* Vol. 4 issue 2, pp. 393-401.

Iwegbue C.M (2007). Metal Fractionation in Soil Profile Automobile Mechanic Wasted Dumps around Port Harcourt. *Waste Management Research*, 25 (6): 585-593

Jia, J; Liu, Y. and Li, G (2009). Contamination Characteristics and its Relationship with Physicochemical Properties of Oil Polluted Soils in Oilfields of China. *Journal of the Chemical Industry and Engineering Society of China*. 60 (3): 726-732

Kayode, J., A., Oyedeji, A. and Olowoyo, O..(2009). “Evaluation of the Effects of Pollution with Spent Lubricating Oil on the Physical and chemical Properties of Soil”.*Pacific Journal of Science and Technology*. 10(1):387-391.

Khamehchiyan, M; Hossein, C. A. and Tajik, M (2007) Effects of Crude Oil and Oil Contamination on Geotechnical Properties of Clayey And Sandy Soils. *Engineering Geology*. 89 (3): 220-229. Doi: 10.1016/j.enggeo.2006.10.009

Kisic, I; Mesic, S; Basic, F; Brkic, V; Mesic, M; Durn, G; Zgorelec, Z; and Bertovic, L (2009). The effect of drilling fluids and crude oil on some chemical characteristics of soil and crops. *Geoderma* 149 (3-4): 209-216.

Murphy, J. and Riley J. P. (1962).A Modified Single Solution Method for Determination of Phosphorus in Natural Waters. *Analytical Chem. Acta.*27: 31 – 36.

Mussa, S. A. B., Elferjani, H. S., Haroun, FA. and Abdelnabi, F. F; (2009).Determination of Available Nitrate, Phosphate, and Sulfate in Soil Samples. *Int. J. Pharm Tech Res.* 1(3): 598-604.

Ndimele, P. E., Saba, A. O., Ojo, D.O., Ndimele, C. C., Anetekhai, M. A. and Erondu, E. S. (2018). Effect of Crude Oil Spillage. *In: The Political Ecology of Oil and Gas Activities in the Nigerian Aquatic Ecosystem*. Ed; Academic Press, London, UK**:** 369-384.

Nelson, D. W. and Summers, L. E. (1996).Total Carbon, Organic Carbon and Organic Matter. *Soil Science Society of America and American Society of Agronomy*, 6775. Segoe Rd, Madison, WI.53711, USA. Methods of Soil Analysis. Part 3. Chemical Methods – SSA Book Series, No. 5.

Nkwoada, A. U., Alisa, C. O; Amakom, C. M (2018). Pollution in Nigerian Auto-Mechanic Villages: A Review. *Environmental Science*, *Toxicology and Food Technology.* 12: (7) 43-54

Odiete, I., V. O. Chude, S. O. Ojeniyi, G. M. Hussiani and S. O. Ogunmoye, (2005). Response of Cotton to Nitrogen Sources in Guinea Savanna Zone of Nigeria. *Nigerian Journal of Soil Science*, 15: 63-68.

Odjegba, V. J. and Sadiq, A. O. (2002) Effect of Spent Engine Oil on the Growth Parameters, Chlorophyll 3and Protein Levels of *Amaranthus hybridus* L. *The Environmentalist*, 22, 23-28. http://dx.doi.org/10.1023/A:1014515924037.

Olson, K.R., Al-Kaisi, M., Lal, R., Morton, L.W. (2017).Soil Ecosystem Services and Intensified Cropping Systems *J. Soil Water Conserv.*, 72, pp. 64A-69A, 10.2489/jswc.72.3.64A

Olugboji, O. A and Ogunwole, O. A. (2008). Use of Spent Engine Oil. *AUJ.T*. 12 (1): 67-71.

Oluwajiose, O; Akinsete, S; Ana, G; Omishakin, A (2015). Soil Contamination by Refined Crude Oil Using *Lumbricus terrestris*as Toxicity Indicator at a Petroleum Product Depot, Ibadan, Nigeria. *Current Journal of Applied Science and Technology* 9(1): 37-46.

Onojake, C.M., _(2004). Petroleum Hydrocarbons and Associated Metals of Ebocha 8 Oil Spill Polluted Site in Niger Delta, Nigeria. M.Sc. Thesis. University of Port Harcourt, Nigeria

Oudot I. I. and K. C Dupont, K. C, (1993), Soil *and Environment, an Introduction.* Oxford Press. London 256-280.

Onwuka M. I, Chude, V. O, and Ogwuegbu G C (2012). Remediation of Spent Engine Oil Polluted Soil Using Two Types of Organic Manure and their Effects on Maize Growth. *Nigerian Journal of Soil Science.* 22(2): 245.

Parlak, M. and Parlak, A. Ö (2011). Effect of Soil Compaction on Root Growth and Nutrient Uptake of Forage Crops. *Journal of Food, Agriculture & Environment.* 9 (3): 275-278

Partha, V., Murthya, N. N. and Saxena, P. R (2011). Assessment of Heavy Metal Contamination in Soil Around Hazardous Waste Disposal Sites in Hyderabad City (India): Natural and Anthropogenic Implications. E3. *J. Environ. Res. Manage.* 2 (2), 027–034.

Pathak, H; Bhatnagar, K. and Jaroli, D, P (2011). Physicochemical Properties of Petroleum Polluted Soil Collected from Transport Najar (Jaipur). *Indian Journal of Fundamental and Applied Life Sciences.* 1(3) 84-89.

Pattnaik, S. and Reddy, M. V (2009).Assessment of Municipal Solid Waste Management in Puducherry (Pondicherry), *India Resource Conservation Recycle*.54, 512–520

Schnecker J, Wild B, Fuchslueger L, Richter A (2014) A Field Method to Store Samples from Temperate Mountain Grassland Soils for Analysis of Phospholipid Fatty Acids. *Soil Biology and Biochemistry* 51: 81–83

Shannon, M. C.(1999). Tolerance of Vegetable Crops to Salinity. *Scientia Horticulturae,* 78(1-4): 5-38

Subin K, Madan K, Udhab R and Anup. K. (2015) Soil Quality Assessment for Different Land Use in the Panchase Area of Western Nepal. *International Journal of Environmental Protection*. Vol. 5 No 1, 38-43.

Sultan, I. Begum, F. Ali, K, Ahmed, S. and Ali, S, (2015) Soil Quality Assessment Using Selected Physicochemical Indicators in Altit, Hunga, Gilgit-Baltisan, *Journal of Biodiversity and Environmental Sciences,* vol 6. No. 1, 454-459.

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.

Udeh, N. U., Nwaogazie, I. and Momoh, Y.. (2016). Bioremediation of a Crude Oil Contaminated Soil Using Water Hyacinth (*Eichhornia crassipes). Advances in Applied Science Research J*. 4.362-369.

Udo, E. J..T. O. Ibia, J. A. Ogunwale, A. O. Ano and I. E. Esu. (2009). *Manual of Soil, Plant and Water Analyses*. Sibon Book Ltd. Lagos.

Udoumoh, I. D. J., Uduak, I. G. and Bassey, D. E.(2019) Effect of Gramaxone Herbicide on Soil Microbial Population at ObioAkpa, Southeast Nigeria *Journal of Agriculture, Environment Resources and Management* ISSN 2245-2943

Wang, Y., Feng, J., Lin, Q., Lyu, X., Wang, X. and Wang, G. (2013). Effects of Crude Oil Contamination on Soil Physical and Chemical Properties in Momoge Wetland of China. *Chinese Geographical Science.* 23. 10.1007/s11769-013-0641-6.