Effect of Spent Engine Oil Discharge on Soil Properties in Selected Automobile Workshop in Calabar, Cross River State, Nigeria

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Abstract

This research was carried out to investigate the effect of spent engine oil (SEO) discharge on soil properties and heavy metal concentrations in selected automobile workshops in Calabar, Cross River State, Nigeria. Soil samples were collected from four different automobile workshops (Atimbo, Etta-Agbor, Elijah Henshaw and Satellite town) in Calabar. Three sampling points were mapped out around each mechanic workshop. The soils were loamy sand and strongly acid. In all the locations, the highest pH values, organic carbon, total nitrogen and available phosphorus were at the point of discharge of the SEO while the exchangeable bases varied across all the locations. Lead, copper and cadmium were higher than the permissible limits whereas iron, manganese and zinc concentrations were below the permissible limits in the studied sites. Spent engine oil should be properly disposed of to avoid heavy metals toxicity in the soil as most of these metals are leached down the profile thereby polluting underground waters which in turn is dangerous to human health.

Keywords: *Automobile mechanic workshops, heavy metals, permissible limit, soil properties, spent engine oil*

1. Introduction

The economy of Nigeria is largely hinged on revenue from petroleum and petro-chemicals. Spent lubricating oil is one of the petro-chemicals reported to be a major and most common soil contaminant in Nigeria, obtained after servicing and subsequent draining of used oil from automobiles engines, it contains potentially toxic polycyclic aromatic hydrocarbons [1] and heavy metals. As engine oil is used in automobile, it picks up a number of additional compounds from engine wear. Once the engine oil is drained off an engine, it is no longer clean because it has picked up materials, dirt particles, and other chemicals during engine operation, thus such lubricating oil is classified as spent engine oil (SEO). The used motor oil, because of the additives and contaminants when disposed can be more environmentally damaging than crude oil pollution [2]. These additives and contaminants may cause both short and long term effect if they are allowed to enter the environment through water ways or soil [3].

Spent engine oil is indiscriminately disposed into gutters, water drains, open vacant plots and farms by auto technicians and allied artisans with workshops on the road sides and open places [3]. The consequences are the environmental pollution, contamination of water bodies, contamination of ground water and toxicity to animal and plants. The release of contaminants into the environment by human activities has increased enormously over the past several decades.

Spent engine oil has become increasingly common source of soil contamination in many urban areas most especially as it cannot be converted into beneficial secondary use. When these contaminants are deposited in soils, they cause higher risk of toxicity and soil infertility. Thus this posed a serious threat to the soil environment and properties [4]. This is because it contains heavy metals which have been found to be harmful to the soil and human health [5]. Heavy metals are those metals having density greater than 5g/cm^3 [6] and usually associated with pollution and toxicity, although some (essential metals) are required by plants and animals at low concentration. Heavy metals occur naturally in the soil environment from the pedogenic processes of weathering of parent materials at levels that are regarded as trace (<1000 mg/kg) and rarely toxic [7, 8]. Metal concentration in soil typically ranges from less than one to as high as 100,000 mg/kg [9]. Due to the disturbance and acceleration of nature's slowly occurring geochemical cycle of metals by man, most soils of rural and urban environments may accumulate one or more of the heavy metals to values high enough to cause risks to human health, plants, animals, ecosystems, or other media [10]. Heavy metals in the soil from anthropogenic sources tend to be more mobile, hence bioavailable than pedogenic, or lithogenic ones [11]. Heavy metals are dangerous because they tend to bioaccumulate, resulting in increase in the concentration of contaminants over time, compared to their concentrations in natural environment [12]. Biotoxic metals accumulate in living things any time they are taken up and stored faster than they are broken down or excreted [13].

As reported by [12] heavy metal influences soil pH and at low pH value most heavy metals and trace elements become more available and biotoxic. Polluted soils were observed to be low in organic carbon and exchangeable bases, but high in cadmium content [12]. Irrespective of the origin of the metals in the soil, excessive levels of many metals can result in soil quality degradation, crop yield reduction, and poor quality of agricultural products, posing significant hazards to human, animals, and ecosystem health [9].

The increase in the number of vehicles in Nigeria has necessitated a higher production and use of SEO. This has subsequently given rise to the generation of large quantities of SEO, at the time of servicing the vehicles. This SEO is considered as ordinary waste by majority of the workers of the automobile mechanic workshops in Nigeria, who dispose this off on soil surface. This practice of disposal is a continuous exercise, except when the SEO is collected by unregistered and unregulated vendors. With increasing number of automobile mechanic workshop in Calabar and many more under construction and the increasing number of vehicles being serviced or repaired at these mechanic workshop from an average of 3 vehicles per workshop per day to an average of 10 vehicles per workshop per day, it can therefore be established that the amount of SEO from vehicles in Calabar is on a steady increase.

Soil pollution has recently been attracting considerable public attention and the magnitude of the problem in our soils calls for immediate action. This study therefore attempts to assess the effect of SEO on soil properties and heavy metal concentrations at the point of discharge of the engine oil as well as on the surrounding soil.

2. Materials and methods

2.1 Description of the study area

The study area, Calabar was selected because it is one of the oldest towns with long standing mechanic workshops in Cross River State. Calabar lies between latitude 5° 32' and 4° 27' N and longitude 7° 15' and 9° 28' E in the Southeastern humid tropical rainforest zone of Nigeria. The town is characterized by a bimodal rainfall pattern with a long rainy season (March- July) and a short rainy season from September to early November after a very short dry spell in late August. The total amount of rainfall within this period ranges from 2000 to 3500 mm annually while the mean temperature ranges between 23 and 33°C. The mean relative humidity is 60 to 90%.

2.2 Field studies

The soil samples used in this study were collected from four (4) different automobile mechanic workshops that were constantly receiving spent engine oil. The locations were Atimbo, Etta-Agbor, Elijah Henshaw and Satellite town. Three sampling points were mapped out around each mechanic workshop. The reference point (1) was at the point of discharge of the spent engine oil into the soil. Point (2) was at a distance of 100 m from the reference point (1). Point 3 was 200 m from the reference point and this served as the control. Composite samples were collected at each sampling point at a depth of 0-30 cm using soil auger. Twelve composite samples were collected in all, three per location. The soil samples collected were air dried, crushed and passed through a 2 mm sieve to remove materials greater than 2 mm in diameter before using it for analysis in the laboratory.

2.3 Laboratory analysis

The prepared soil samples were then taken to the laboratory for physico-chemical analysis using standard procedures as outlined by [14]. For heavy metals determination, the prepared soil samples were digested with perchloric and nitric acid and Cd, Pb, Cu, Mn, Fe and Zn were read using a buck 205 model Atomic Absorption Spectrophotometer (AAS).

2.4 Interpretation guide for evaluating chemical properties and heavy metal concentrations in soil

The result of this study were interpreted using the interpretation guide for evaluating soil chemical properties as adapted from [15] in Table 1.

Table 1: Interpretation guide for evaluating soil chemical properties

Parameter	Rating class			
	Low	Moderate	High	Very high
Soil pH	< 4.5 (extremely acid) 4.5 – 5.0 (very strongly acid) 5.1 – 5.5 (strongly acid)	5.6 – 6.0 (moderately acid) 6.1 – 6.5 (slightly acid)	> 9 (very strongly alkaline)	
Organic carbon (%)	< 1.0	1.0 – 1.5	1.5 – 2.0	> 2.0
Total nitrogen (%)	< 0.2	0.2 – 0.5	0.5 – 1.0	> 1.0
Available P (mg/kg)	< 8	8– 20	> 20	-
Exch. Ca (cmol/kg)	< 5	5 -10	10 – 20	> 20
Exch. Mg (cmol/kg)	< 1	1 – 3	3 – 8	> 8
Exch. K (cmol/kg)	< 0.3	0.3 – 0.6	0.6 – 1.2	> 1.2
Exch. Na (cmol/kg)	< 0.3	0.3 – 0.7	0.7 - 2	> 2
TEB (cmol/kg)	< 12	12 – 25	25 - 40	> 40
Base saturation (%)	< 40	40 - 60	60 - 80	> 80

Source: [15]

3. RESULTS AND DISCUSSION

3.1 Effects of spent engine oil discharge on the soil properties

The particle size distribution of the soil reveals that the soil texture is loamy sand irrespective of the location and sampling points (Table 2). This shows that the soils are coarse textured with a high content of sand giving dominant textural class of loamy sand in all the locations. The soil texture was not affected by the spent engine oil discharge.

The soil pH ranged from 5.4-5.5 in Atimbo, 4.6-5.2 in Etta-Agbor, 4.4-5.2 in Elijah Henshaw and 4.4-5.1 in Satellite Town (Table 3). In all the locations, the highest pH values were obtained from the point of discharge of the spent engine oil with a mean value of 5.3 (strongly acid)while the surrounding soil and control had the same mean pH value of 4.7 (very strongly acid). However, these values gave an indication of an acidic condition of the soils. Based on the rating given by [15] in Table 1, the soil pH ranged from extremely acid to strongly acid. The pH values obtained in the soils of the study area were lower (4.4 to 5.5) than the pH range of 5.43 to 6.79 obtained from spent engine oil contaminated soil in mechanic workshop in Imo state by [16]. Soil pH is a major factor influencing the availability of elements in the soil for plant uptake [17]. Many metal cations are more soluble and available in the soil solution at low pH (below 5.5) including Cd, Cu, Hg, Ni, Pb, and Zn [18], the retention of metals to soil organic matter is also weaker at low pH, resulting in more available metal in the soil solution for root absorption[12,16].

The organic carbon (OC) content ranged from 1.5-2.0% in Atimbo, 0.3-2.9% in Etta-Agbor, 0.8-2.4% in Elijah Henshaw and 1.6-2.5% in Satellite Town (Table 3). Generally, the OC content ranged from low to high in all the locations based on the soil rating given by [15] in Table 1. In all the locations, organic carbon content was highest at the point of discharge of the spent engine oil (2 – 2.9%) having a mean value of 2.5%, the surrounding soil and control had the same mean OC value of 1.2%. This contradicts the findings of [12] who reported higher organic carbon content in unpolluted site than in automobile polluted site but agrees with the findings of [19] who reported higher OC values in crude oil polluted soils than the non-contaminated site.

Table 2: Effects of spent engine oil discharge on the particle size distribution of the soil

Location	Particle size distribution (%)			Texture
	Sand	Silt	Clay	
Point of discharge				
Atimbo	72	15	13	Loamy sand
Etta-Agbor	82	11	7	Loamy sand
Elijah Henshaw	75	13	12	Loamy sand
Satellite Town	73	18	9	Loamy sand
Mean	76	14	10	
Surrounding soil				
Atimbo	74	15	11	Loamy sand
Etta-Agbor	79	14	7	Loamy sand
Elijah Henshaw	73	18	9	Loamy sand
Satellite Town	82	13	5	Loamy sand
Mean	77	15	8	
Control				
Atimbo	72	16	12	Loamy sand
Etta-Agbor	84	11	5	Loamy sand
Elijah Henshaw	82	13	5	Loamy sand
Satellite Town	79	14	7	Loamy sand
Mean	79	14	7	

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Table 3: Effects of spent engine oil discharge on chemical properties of the soil

Location	Soil pH	Org. C (%)	Total N (%)	Av. P (mg/kg)	Exchangeable bases (cmol/kg)				Exchangeable acidity (cmol/kg)		TEB (cmol/kg)	ECEC (cmol/kg)	BS (%)
					Ca	Mg	K	Na	Al	H			
Point of discharge (contaminated site)													
Atimbo	5.5	2.0	0.16	19.25	6.4	1.0	0.12	0.09	0.64	0.14	7.61	8.89	85.6
Etta-Abgor	5.2	2.9	0.24	17.75	7.4	1.0	0.12	0.08	0.22	0.13	8.60	8.95	96.1
Elijah Henshaw	5.2	2.4	0.20	24.12	6.0	2.8	0.11	0.08	0.24	0.18	8.99	9.41	95.5
Satellite Town	5.1	2.5	0.20	22.00	5.8	2.0	0.10	0.07	0.56	0.14	7.97	8.67	91.2
Mean	5.3	2.5	0.20	20.78	6.4	1.7	0.11	0.08	0.41	0.14	8.29	8.98	92.1
Surrounding soils													
Atimbo	5.4	1.5	0.12	15.12	8.6	3.2	0.11	0.09	0.18	0.14	12.00	12.32	97.4
Etta- Agbor	4.6	0.8	0.07	17.75	5.2	1.2	0.10	0.07	0.66	0.48	6.57	7.71	85.2
Elijah Henshaw	4.4	0.8	0.07	22.87	4.0	2.8	0.08	0.06	0.40	0.75	7.28	8.43	86.4
Satellite Town	4.4	1.6	0.13	16.62	5.6	3.2	0.09	0.08	0.86	0.40	8.97	10.23	87.7
Mean	4.7	1.2	0.09	18.09	5.9	2.6	0.09	0.07	0.52	0.44	8.70	9.67	89.2
Control													
Atimbo	4.8	1.7	0.14	14.00	4.8	2.4	0.09	0.07	0.60	0.15	7.36	8.11	90.8
Etta-Agbor	4.6	1.6	0.12	23.50	5.4	1.3	0.10	0.08	0.44	0.72	6.88	8.04	85.6
Elijah Henshaw	4.9	0.7	0.06	19.17	4.8	1.6	0.10	0.07	0.36	0.40	6.57	7.33	89.6
Satellite Town	4.6	0.8	0.07	17.75	5.2	1.2	0.10	0.07	0.66	0.48	6.57	7.71	85.2
Mean	4.7	1.2	0.09	18.60	5.0	1.6	0.09	0.07	0.51	0.43	6.84	7.79	87.8

The available phosphorus ranged from 14.00-19.25 mg/kg in Atimbo, 17.75-23.50 mg/kg in Etta-Agbor, 10.17-24.12 mg/kg in Elijah Henshaw and 16.62-22.00 mg/kg in Satellite Town (Table 3). Available phosphorus was highest at the point of discharge of spent engine oil (17.75- 24.12 mg/kg) with a mean value of 20.78 mg/kg than the mean values of surrounding soil (18.09 mg/kg) and control (18.60 mg/kg). This contradicts the findings of [12] who reported higher P values in unpolluted site than in automobile polluted site but agrees with the findings of [19] who reported higher P values in crude oil polluted soils than the non-contaminated site. The P values were rated moderate to high based on the rating given by [15].

Total nitrogen ranged from 0.12 – 0.16% in Atimbo, 0.07 – 0.24% in Etta –Agbor, 0.07 – 0.20% in Elijah Henshaw and 0.13 – 0.20% in Satellite Town (Table 3). Total nitrogen content in the soil was higher at point of discharge of SEO with a mean value of 0.20% compared with the surrounding soils and control which had the same mean value of 0.09%. However, [12] reported higher values in unpolluted site than in polluted site whereas [19] reported higher total N values in soil contaminated with crude oil than in the non-contaminated site. The values were generally low except at the polluted sites which had moderate level of nitrogen. The low levels of nitrogen in the study sites is typical of the highly weathered soils of the humid tropics and may be attributed to high nitrogen losses through leaching resulting from high rainfall [20].

Exchangeable calcium content ranged from 6.4-8.6 cmol/kg in Atimbo, 5.2-7.4 cmol/kg in Etta- Agbor, 4.0-6.0 cmol/kg in Elijah Henshaw and 5.6-5-8 cmol/kg in Satellite Town. Exchangeable magnesium ranged from 1.0-3.2 cmol/kg in Atimbo,1.0-1.3 cmol/kg in Etta-Agbor, 2.8-2.8 cmol/kg in Elijah Henshaw and 2-3.2 coml/kg in Satellite Town. Exchangeable potassium ranged from 0.09-0.12 cmol/kg in Atimbo, 0.10-0.12 cmol/kg in Etta-Agbor, 0.08-0.11cmol/kg in Elijah Henshaw and 0.09-0.10 cmol/kg in Satellite Town. Exchangeable sodium ranged from 0.07-0.09 cmol/kg in Atimbo, 0.07-0.08cmol/kg in Etta-Agbor, 0.06-0.08 cmol/kg in Elijah Henshaw and 0.07- 0.08 cmol/kg in Satellite Town. Total exchangeable bases in the study sites were generally low (less than 12 cmol/kg). This is because the coarse textured soil (sand) is commonly lower in both clay and humus content. The TEB of most soil increases with pH. At very low pH values, the TEB is generally low. The low value of TEB in the soil samples implies low fertility of the contaminated and uncontaminated soils.

The base saturation of polluted and unpolluted soils were rated high based on the fertility rating given by [15] in Table 1 as the values were all greater than 80%.

3.3 Effects of spent engine oil discharge on heavy metal concentrations

The concentrations of heavy metals as influenced by spent engine oil discharge are presented in Table 4. The concentration of lead (Pb) ranged from 500.1 - 580 mg/kg with a mean value of 530.4 mg/kg. Atimbo location had the highest concentration of Pb (580.0 mg/kg) at the point of discharge (POD) followed by Satellite Town (539.6 mg/kg) while the least concentration was obtained from the control (500.1 mg/kg). Lead concentration in all the contaminated soils including the control exceeded the permissible limit of 200 mg/kg given by [21] and 250 mg/kg given by [22]. The high concentration of Pb could be due to low pH values recorded in the area and also due to the contamination of the soil with SEO. This is in line with the findings

Table 4: Effects of spent engine oil discharge on heavy metal concentrations in the soil

Location	Heavy metal concentrations (mg/kg)					
	Lead (Pb)	Copper (Cu)	Iron (Fe)	Manganese (Mn)	Cadmium (Cd)	Zinc (Zn)
Point of discharge (contaminated site)						
Atimbo	580.0	260.1	1420.0	422.00	4.91	138.34
Etta-Agbor	519.2	215.5	1218.0	402.00	5.21	120.00
Elijah Henshaw	513.0	235.2	1306.0	413.33	5.03	110.33
Satellite Town	539.6	215.3	1215.0	408.00	4.50	130.17
Control	500.1	213.0	1212.0	308.00	3.70	119.20
Mean	530.4	227.8	1274.2	390.67	4.67	123.61
Permissible limit						
Nangia, 1991	200	100	55,000	4000	0.7	300
Rowell, 1994	250	135	-	-	3	300

of [16] and [12] who reported that most heavy metals and trace elements become more available and bio-toxic at low pH values. The high concentration of Pb in the area may be as a result of the conversion of non-polar Pb compounds to aqueous Pb as it passes through clay soil or liners in the soil profile [16].

The concentration of copper (Cu) ranged from 213 – 260.1 mg/kg with a mean value of 227.8 mg/kg. The highest value was obtained from Atimbo mechanic workshop while least value was from the control. The concentrations of copper in all the contaminated sites and control were higher than the permissible limit of 100 mg/kg according to [21] and [22]. It has been pointed out by [18] that many metal cations of which copper were included are more soluble and available in the soil solution at low pH (below 5.5). Copper is a micro element which is essential in plant growth and occurs generally in soil, sediments and air. Copper content has been reported to differ according to the soil type and pollution source. The high concentration may be as a result of burnt vehicles along the major roads because copper is commonly found in electrical wiring.

Iron ranged from 1212.0 – 1420 mg/kg with a mean value of 1274.2 mg/kg. The highest value was obtained from Atimbo location (1420 mg/kg) followed by Elijah Henshaw location (1306 mg/kg) while the least concentration of iron was from control

(1212.0 mg/kg). The permissible limit according to [21] is 55, 000 mg/kg. Based on the permissible limits, iron concentration was very low in the studied sites.

Manganese concentration ranged from 308.00 - 422.00 mg/kg with a mean value of 390.67 mg/kg. The least concentration of Mn was from the control (308 mg/kg) while the highest value of 422.00 mg/kg was recorded in Atimbo location. Compared with the permissible limit of 4000 mg/kg given by [21], the concentration of Mn in all the polluted sites and control was low. This is in agreement with the findings of [19] who reported higher concentrations in crude oil contaminated soils than in uncontaminated soil. However, their values which ranged from 13.24 to 33.39 mg/kg were far lower than the values obtained in the SEO contaminated in the study sites. This may be attributed to the fact pointed out by [2] that used motor oil, because of the additives and contaminants when disposed can be more environmentally damaging than crude oil pollution.

Cadmium concentration ranged from 3.70 - 5.21 mg/kg a mean value of 4.67 mg/kg. The highest concentration was from Etta-Agbor (5.21mg/kg) while the least was from the control (3.70 mg/kg). The permissible limit according to [21] for cadmium is 0.7 mg/kg while [22] gave 3 mg/kg as the permissible limit. Cadmium concentration in both the contaminated and uncontaminated sites exceeded the permissible limits given by [21] and [22]. This view has also been reported by [12, 16, 18]. Mean value of 4.44 mg/kg has been reported by [12] for cadmium in automobile polluted soils in Southeastern Nigeria while the unpolluted sites had a mean value of 0.46 mg/kg. Cadmium is vey biopersistent but has few toxicological properties and once absorbed by the soil remain resident for many years.

Zinc ranged from 110.33 - 138.34 mg/kg with a mean value of 123.61 mg/kg. Compared with the permissible limit of 300 mg/kg, all the locations had low concentration of zinc. This is in agreement with the findings of [19] who recorded lower concentrations of zinc in crude oil contaminated soils.

4. Conclusion

In all the locations, organic carbon, total nitrogen and available phosphorus were highest at the point of discharge of the spent engine oil while the exchangeable bases varied across all the locations irrespective of sampling point and location. Lead, copper and cadmium concentrations were higher than the permissible limits whereas iron, manganese and zinc concentrations were below the permissible limits in the studied sites. From the results obtained, it can be concluded that the soils at point of discharge were high in most of the chemical properties and heavy metals measured. Spent engine oil should be properly disposed of to avoid heavy metals toxicity in the soil as most of these metals are leached down the profile thereby polluting underground waters which in turn is dangerous to human health.

REFERENCES

[1] M. R. Shar, M. Agrawal, and F. M. Marshall (2009). Heavy metals in vegetables collected from production and market sits of a tropical urban area of India, *Food Chem toxicol*., 47: 58 – 91.

[2] O. P. Abioye, P. Agamuthu, and A. R. Adul Aziz (2012): Biodegredation of used motor oil in soil using organic waste amendments. *Biotechnology resource institute*, doi: 1155/2012/587041

[3] G.O. Anoliefo, and D. E. Vwioko (2001). "Tolerance of chromolaena odorata (L) K and R. grown in soil contamination with spent lubrication oil", *Journal of tropical Biosciences, 1: 20-24.*

[4] O. M. Adedokun, and A. E. Ataga (2007). Effects of amdendment and bioaugumentation of soil polluted with crude oil, automotive gasoline oil and spent engine oil on the growth of cowpea (vigna unguiculata walpl). *Scientific research and Essay*, 2 (5): 147-149.

[5] J. H. Duffus (2002). "Heavy metals" a meaningless earns? *Pure applied chemistry* 74:793-807.

[6] L. J. Goje, F.U. Maigari, and M. P. Jadeed (2017). Determination of the Level of Some Heavy Metals and Trace Elements in River Gongola of Adamawa State, Nigeria. *International Journal of Innovative Science, Engineering & Technology*, 4 (1): 163- 169.

[7] M. R., Singh (2007). Impurities-heavy metals: IR prespective. Available from: http://www.usp.org/pdf/en/meetings/asmeetingindia/2008sessions4trackIPDF.

[8] A. Kabata, and H. Pendias (2001). *Trace metals in soils and plants*, CRC press, Boca Ration, Fla, USA, 2nd edition.

[9] X. X. Long, X. E. Yang, and Ni Wz (2002). Curent status and prospective on phytoremediation of heavy metal polluted soils. *April Ecol*: (13) 757-62

[10] J. J. D'Amore, S. R. Al-Abed, K.G. Scheckel, and J. A. Ryan (2005)."Methods for speciation of metals in soils, Journal of environmental quality. 34: (5) 1707-1745.

[11] M. Kaasalainen, and Halla M. Yli. (2003). Use of sequential extraction to assess metal partitioning in soils, environmental pollution. 126 (2) 225-233.

[12] B. N. Ndukwu, E. U. Onweremadu, C. M. Ahukaemere, E. E. Ihem, U. N. Nkwopara and D. N. Osujieke (2015). Distribution and concentration of cadmium in automobile polluted soils in Owerri, South Eastern Nigeria. *Nigerian Journal of Soil Science*, 25: 135-145.

[13] S. A. Mashi, and M. M. Alhassan (2007). Effects of waste water discharge on heavy metals pollution in Fadama soils in Kano City, Nigeria. *Biomedical and Environmental Sciences*, 20: 70- 77.

[14] E. J. Udo, T.O. Ibia, J. O. Ogunwale, A.O. Ano, and I. E. Esu (2009). Manual of soil plant and water analysis. Sibon Books Ltd Lagos.

[15] A. O. Adaikwu, and A. Ali (2013). Assessment of some soil quality in Benue State. *Nigerian Journal of Soil Science*, 23(2) 66-75.

[16] U. I. Uchendu, and P. A. Ogwo (2014). The Effect of Spent Engine Oil Discharge on Soil Properties in an Automobile Mechanic Village in Nekede, Imo State, Nigeria. *IOSR Journal of Environmental Science, Toxicology and Food Technology,* 8 (11): 28-32.

[17] H. Marschner (1995). *Mineral nutrition of higher plants* (2nd ed.). New York: Academic Press.

[18] M. B. McBride (1994). *Environmental chemistry of soils*. New York: Oxford University Press.

[19] E. D. Chukwu, and B. T. Udoh (2014). Effect of crude oil and industrial wastes pollution on some soil chemical properties in Ikot Abasi, Niger Delta Area, Nigeria. *Proceedings of the 38th Annual Conference of the Soil Science Society of Nigeria*, 83-88.

[20] N. C. Brady, and R. R. Weil (1999). *The Nature and Properties of Soils*. (12th Edition). Prentice Hall, New Jersey.

[21] S. B. Nangia (1991). *Soil Pollution*. New Delhi, Ashish Publishing House.

[22] D. L. Rowell (1994). *Soil Science Methods and Applications*. Longman Scientific and Technical, Longman Group UK.