academicJournals

Vol. 5(5), pp. 136-146, May, 2013
DOI:10.5897/JECE2013.0280
ISSN 2141-226X ©2013 Academic Journals
http://www.academicjournals.org/JECE

Journal of Environmental Chemistry and Ecotoxicology

Full Length Research Paper

Assessment of direct soil pollution in automobile junk market

Nwachukwu M. A.*, Ntesat B. and Mbaneme F. C.

Department of Environmental Technology, Federal University of Technology Owerri, Nigeria.

Accepted 9 May, 2013

Crude recycling of used engines and transmissions in no small measure is of great concern to environmental health and safety. In this study, topsoil across Obosi automobile junk market (alias Mgbuka Obosi) near Onitsha, Nigeria, is investigated for heavy metal and polycyclic aromatic hydrocarbon (PAH) enrichment. Fifteen composite soil samples were randomly collected in addition to the background samples at 0-6 and 6-15 cm depths. Samples were properly digested and subjected to spectroscopic analysis using Atomic Absorption Spectrometer (AAS) for trace metals, and gas chromatography for PAH. The result shows that trace metals concentration (ppm) in 0-15 cm depth are well above the background values with Pb in excess of international standards. Metal enrichment is in the order of Pb>Zn>Mn>Cr>Cu>Ni>Cd. Analysis of PAH found in fluorine and anthracite as addition in the Automobile Junk Market (AJM) soil. Mean pH was 3.24 in the AJM soil, against 7.0 in the background. Urgent environmental alert therefore requires AJM operations worldwide to be environmentally friendly.

Key words: Soil pollution, trace metals, polycyclic aromatic hydrocarbon (PAH), junk engines-transmissions, developing countries.

INTRODUCTION

Following the wave of global economic recession, automobile wastes, particularly knockdown engines are continually transferred from industrialized nations to developing countries for recycling and reuse. Much as this business has exceeded the permits of the World Trade Organization (WTO) as a type of waste transfer, it has found a place in Nigeria. Nevertheless, the goal of this paper is not about justification of the disposal of automobile waste engines to poor developing countries. For proper assessment, environmental monitoring of waste transfer can be considered in four statuses as presented in the model (Figure 1). Status 1; gives account of the environmental impact at the very point of where the waste was dumped in the receiving country, before it was moved for recycling activity. Status 2; is the environmental impact of the waste at the site of recycling. Status 3 assesses the environmental impact of the waste as it is reused. This status attracts longer monitoring time than status one and two which does not always hold. Recycled engines often fail at test run and become unserviceable or abandoned in junk markets and mechanic villages constituting the Status 4 (Figure 1).

As new genuine automobile spare parts become more and more expensive or unavailable, motorist in developing countries have resorted to the use of fairly used parts sold in junk markets. Container loads of used engines and transmissions classified as waste in many industrialized nations are now transferred to developing countries where they are refurbished and sold in junk markets. Automobile junk business is now on the rise and

*Corresponding author. E-mail: futo.essg@hotmail.com.

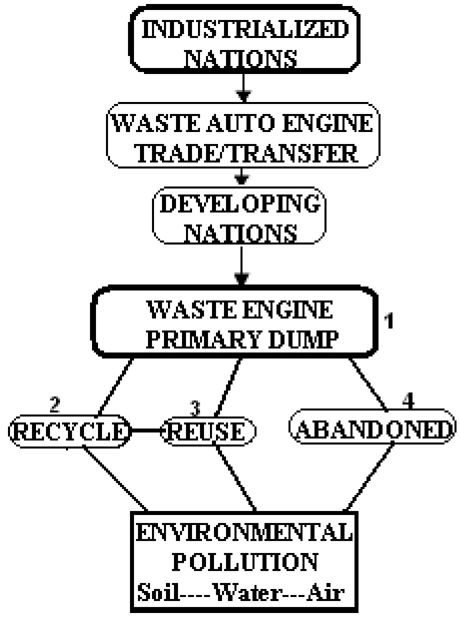

Figure 1. A model describing status and environmental concern of knockdown automobile engines transferred to poor developing countries.

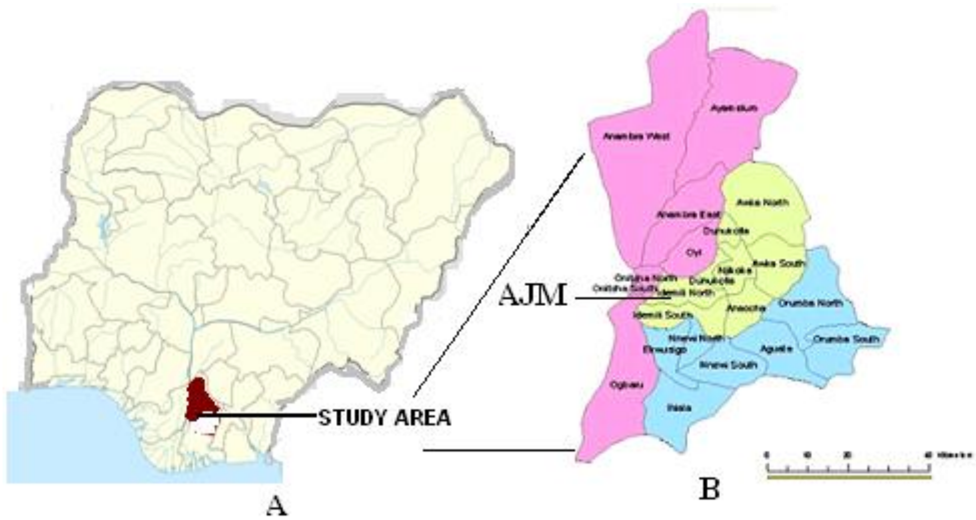

Figure 2. A: Map of Nigeria showing Anambra. B: Map of Anambra state, showing the Obosi AJM in Idemili North County.

also ranking high in environmental degradation or soil pollution in many African countries. Automobile junk markets generate huge financial benefits, but also terrible health and environmental hazards, for not being properly managed. It is observed that a lot of revenue is obtained from AJMs, with Obosi AJM probably the largest in the West Africa sub region. Proceeds per individual income from the Obosi AJM greatly contributed to the position of Onitsha city as the largest most popular open market in West Africa. Obosi AJM (alias Mgbuka Obosi) is actually located in Idemili North local government county of Anambra state (Figure 2A and B).

Despite the huge sum of revenue, it is improper to neglect some of the hazards associated with the AJM operations. Possible impacts of the AJM to Idemili River (Figure 3), the soil pollution, bioavailability to plants and

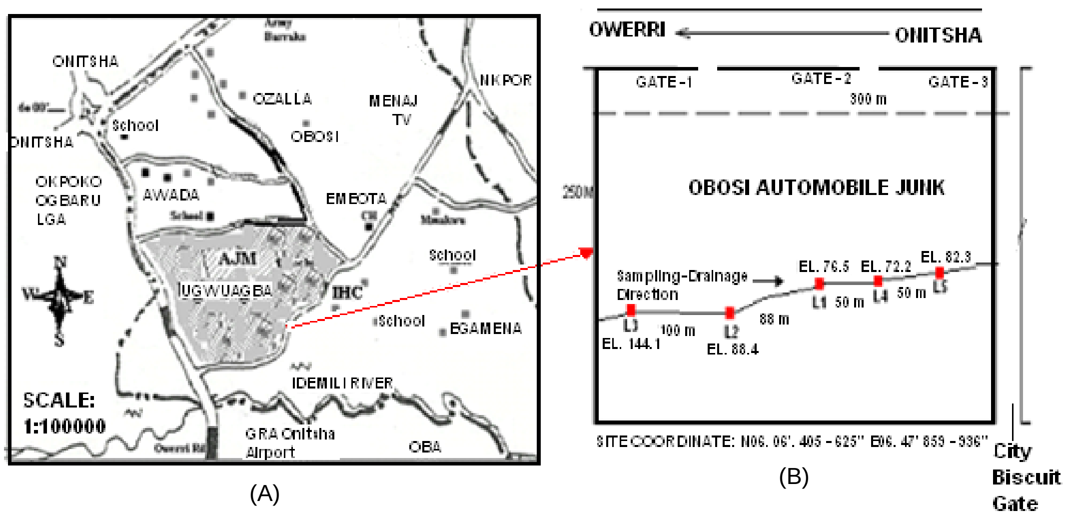

Figure 3. (a) Part of Idemili LGA showing Obosi AJM. (b) Sketch (not to scale) of the AJM showing sample collection points and their elevation.

Figure 4. Photographs showing sections of *Mgbuka-Obosi*; open AJM.

food crops, and the consequent impacts of spent oil on the crude engine recyclers are critical (Dioka et al., 2004).

Automobile junk markets similar to mechanic villages is another place where the less privileged and school drop-outs could work-in and become established at little or no cost. As a result, AJM similar to a mechanic village can be seen as a center for poverty alleviation (Nwachukwu et al., 2010b). The ever increasing number of AJMs and knockdown engines over a wide geographical spread will constitute a severe environmental problem this millennium, if not properly addressed. For example, the Obosi AJM is situated by the Idemili River at a slope of 10%, whereas the Idemili River is the primary source of water and aquatic food to Onitsha metropolis. The AJM (Figure 4) is located uphill which facilitates the quick transport of deleterious contaminants to the residential area and the Onitsha urban waterway. The emerging green automobile technology in developed nations may worsen the matter. This will cause an unprecedented rise in the number of high fuel guzzling used automobile engines and transmissions transferred to developing countries by the end of the first quarter of this century.

The unprecedented increase in transfer of junk automobile engines and transmissions from industrialized to developing nations of the world may be reciprocated by more AJMs, and mechanic villages. Because of this, the environmental impacts of automobile junk markets may cause greater concern to land use planning, water resources management, and public health. Topsoil within and around AJMs become heavily contaminated by toxic trace metals in many parts of Nigeria. Storm water from AJMs get into the waterways untreated, and there is no protection to both surface and groundwater within and around AJMs. There is also no form of groundwater monitoring wells for safety either by government establishments or by non governmental agencies. While an automobile engine is running, the motor oil collects

Table 1. Content of various elements in soils (Lindsay, 1979).

Metals	Selected average (mg/kg)	Common range (mg/kg)
Al	71,000	10,000-300,000
Fe	38,000	7,000-350,000
Mn	600	20-3,000
Cr	100	1-1,000
Zn	50	10-300
Ni	40	5-500
Cu	30	2-100
Pb	10	2-200
As	5	1.0-50
Se	0.3	0.1-2
Cd	0.06	0.01-0.7
Ag	0.05	0.01-5
Hg	0.03	0.01-0.3

particles of heavy metals such as Lead, Cadmium, Chromium, Iron, Manganese, Zinc, and Copper, through wear and tear. Collection of these particles increases as the engines gets older, which knockdown engines are characterized by.

Contaminants such as hydrocarbons, heavy metals, pesticides, and herbicides have been known to easily pollute soils by simple absorption when spilled on the ground. They also have direct toxic effects when released into the aquatic environment and the sediments constitute the sink for these pollutants (Forstner et al., 1998; Fleeger et al., 2003; Adekola and Eletta, 2007). Sediments act as carriers and possible sources of pollution because heavy metals are not permanently fixed by them and can be released back to the water column by changes in environmental factors (Horsfall et al., 1999; Adekola and Eletta, 2007). Trace metals gain access into the river system from both natural and anthropogenic sources and these get distributed into the water body and sediments during the course of their transportation. A catchment area containing mineralized rocks will usually have elevated metal levels as the trace metal content of rivers in the catchment area and by their mobility (Olajire and Imeokparia, 2001; Adekola and Eletta, 2007). Trace metals of interest in this study include the following: Lead (Pb), Chromium (Cr), Cadmium (Cd), Iron (Fe),Zinc (Zn), Manganese (Mn), Copper (Cu),and Nickel (Ni) within the near surface soil profiles of 'Mgbuka'- Obosi (Figure 3). Today, landfills and other solid wastes disposal sites are major targets of pollution because of rainfall and base flow, taking these highly contaminated substances into rivers, streams, and waterways, inadvertently used by residents in such areas (Asonye et al., 2007). Poor development of automobile junk market is possible to cause significant ecological impacts relating to depth, degree, and distance of distribution of metal contaminants in the soil. It is obvious, that trace metal concentration in soils is usually high near the point source, which will always dispel with both distance and depth owing to increasing limits in mobility and physical dilution. Depth of dispersion accounts for the tendency to groundwater pollution. However the threat posed by trace metals to human health and the environment is dependent on their speciation in the soil solution rather than the total concentration (Nwachukwu et al., 2011).

Metals in soil

Soils naturally contain trace levels of metals. The presence of metals in soils, therefore, is not indicative of contamination. The concentration of metals in uncontaminated soil is primarily related to the geology of the parent rock material from which the soil was formed. Depending on the local geology, the concentration of metals in a soil may exceed the ranges listed in Table 1 below. For example, seleniferous concentration in non-seleniferous soils in the United States ranges from 0.1 to 2 mg/kg. In seleniferous soils, selenium ranges from 1 to 80 mg/kg, with reports of up to 1200 mg/kg in certain locations (McNeal and Balistrier, 1989). Table 1 below presents the content of various elements in soils (Lindsay, 1979).

Immobilization of metals by mechanisms of adsorption and precipitation will prevent movement of the metals to groundwater. Metal-soil interaction is such that when metals are introduced at the soil surface, downward transportation does not occur to any great extent unless the metal retention capacity of the soil is overloaded, or metal interaction with the associated waste matrix enhances mobility. Changes in soil degradation of the organic waste matrix, change in pH, redox potential, or soil solution composition, due to remediation and weathering processes, enhance metal mobility (Mclean

Table 2. Sample collection distribution

S/N	Location	Sample/Replicates	Homogenized	Depth per sampling(cm)
1	1	9	3	0-6/6-15
2	2	9	3	0-6/6-15
3	3	6	2	0-6/6-15
4	4	6	2	0-6/6-15
5	5	6	2	0-6/6-15
6	6	9	3	0-6/6-15

and Bledsoe, 1992).

The concentration of metals in the soil solution, at any given time, is governed by a number of interrelated processes, including inorganic and organic complexes. These processes are oxidation/reduction reactions, precipitation/dissolution reactions, and adsorption/desorption reactions. The ability to predict the concentration of a given metal in the soil solution depends on the accuracy with which the multiphase equilibrium can be determined or calculated (Mclean and Bledsoe, 1992). In high concentrations, trace metal ions react to form toxic compounds in both flora and fauna cells (Nies, 1999). However, to have a toxic effect, trace metal ions must first gain access into the cell. Though trace elements are usually present in the environment, they are potentially extremely toxic and not only would they affect the biota at a water soluble concentration at less than 1 part per million (ppm), humans can be grossly affected (Asonye et al., 2007).

Petroleum hydrocarbon components are quite toxic, making the waste oil from spent lubricants a major factor in terms of soil pollution. Due to its toxicity when spilled on the soil, it kills the herbaceous vegetation of the affected area. Spent oil disposal in the soil system spells more hazardous consequences for soil borne vegetation and most soil living organisms than in the case with air pollution. Man and other surface living creature are no exceptions. Often, though depending on the extent of spill, the soil area under spill becomes oil-bathed. This means a total occupancy of the interstitial pores of the system by oil thereby preventing oxygen availability to bentic organisms. In such situations, oil continues to permeate the upper strata of soil which forms the natural base of most organic interactions, percolating through the grains in different directions. The rate of percolation and the distance to be reached depends much on the porosity and permeability of the soil. And when this occurs it inhibits or completely rules out the diffusion of oxygen into the soil system. This leads to suffocation of the soil life, also, in the absence of soil aeration reactions (organic or inorganic) proceeding under aerobiosis are halted and the generation of organic nutrients by plants is ruled out (Abioye et al., 2012). Chemical properties of soil and percentage organic matter increased from 1.34 to 2.62 in polluted soils. Statistical analysis shows that high levels of pollution also inhibited germination of plants (Ogboghodo et al., 2004).

MATERIALS AND METHODS

A primary sample and two replicates were collected from five different locations along the major road traversing the Obosi AJM. The primary sample and the two replicates for each sample point were properly homogenized to obtain a true representative sample for testing. This became necessary in order to reduce cost and test multiplications. Samples were obtained by hand auger at drainage collection points, in the direction of natural drainage (South-East to North-West). Background samples were similarly obtained one kilometer off the AJM, and against the natural direction of drainage (approximately North-West to South-East) as control. A total of 15 samples were obtained at 0-6 cm and 6-15 cm depths in all locations. Sampling procedure was shown in Figure 3b, and as contained in Table 2.

Samples were collected simultaneously, usually wrapped in an aluminum foil and then put in polyethylene bags for onward transportation to the laboratory. Samples were air-dried in the laboratory for few days at room temperature, and large objects (sticks, stones, etc.) were removed. Samples were equally subjected to screen effects in sieves, through a 0.05 mm mesh screen to obtain homogenous particle sizes. Samples that penetrated the screen were collected in small black polyethylene bags for further preparation. All coarse grains were first crushed using mortar and pestle before sieving. The sieved samples were stored in pre-cleaned sample bottles with covers, and labeled properly for digestion. Two composite samples were prepared for PAH measurement. Replicate samples of locations 1-3 were homogenized to obtain composite sample (a), while sample locations of 4 and 5 were homogenized to make composite sample (b).

Digestion procedure

The composite samples, each derived from three replicates were digested following the US Environmental Protection Agency (USEPA) (2001) method 3050B. The analysis was on a GBC AVANTA Atomic Absorption Spectrometer (AAS), at precision and accuracy better than 10%. PAH was determined using gas chromatograph, which is a control system to determine the level of hydrocarbon in soil samples after extraction of the sample with chloroform. The mixture of sample and chloroform was allowed to stand for 10 minutes and the lower portion (20 ml) was filtered into sample cell. Results were obtained using the store program number and appropriate wavelength for PAH content in the soil. Two grams of each sample was weighed in an electronic weighing balance, adding solvent (dichloromethyl/chloroform) in Ama specimen bottles. Sodium sulphate was added in order to dehydrate water

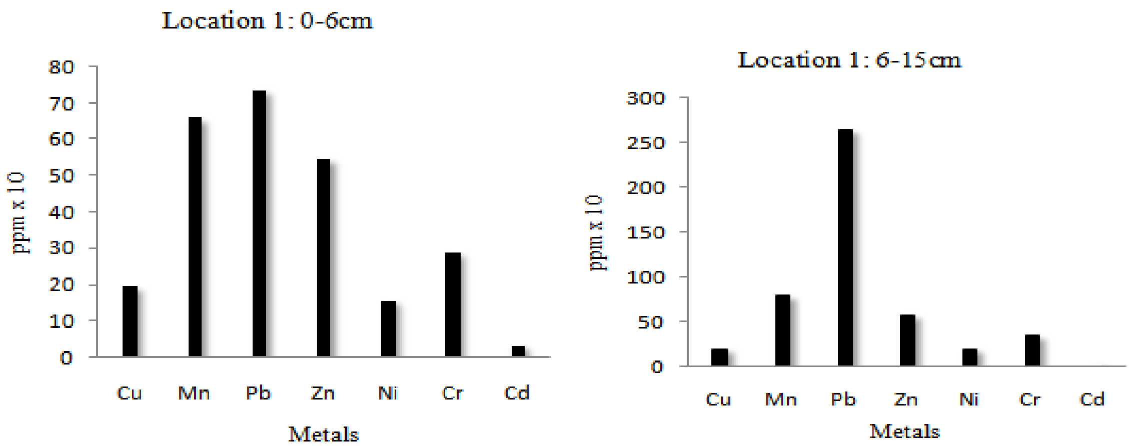

Figure 5. Trace metals concentration at location 1.

from the sample. The Ama bottles are then subjected to UV metric analysis to get total hydrocarbon content (THC) which must be directly proportional to total petroleum hydrocarbons. Finally, 1µl of the residue was taken from the evaporated sample at room temperature, and then injected into the already calibrated gas chromatograph. Interpretation of the PAH speciation was obtained in three gases at 30 psi for moderation.

Applicable statistical relations

In this study, Microsoft Excel was used in the data processing. Metals concentration in the AJM and in the background were determined and compared. Three statistical criteria were used in the pollution assessment:

(a) The pollution index (pi) per metal as stated in Equation 1,
(b) The degree of iron and other metal enrichment (DME) in $mgkg^{-1}$ and
(c) Pollution factor (pf) as demonstrated by Nwachukwu et al. (2010 a, b).

The ratio of mean Mu of the concentration of metals above the background values, with the mean of total metal concentration in the AJM is the pollution factor (Equation 2). The statistical relations for these criteria are shown as follows:

$$Pi = \frac{Mi}{Bi} \quad (1)$$

$$Pf = \frac{\text{Mu of M-B}}{\text{Mean of M}} \quad (2)$$

Where Mi is the concentration of the i^{th} pollutant in ppm obtained in the AJM; Bi is the relative background concentration of i^{th} pollutant (ppm), Mu is the value at which the distribution is symmetrical and equal with respect to mean.

Crowder (1992) and Nwachukwu et al. (2010a) have used mean and Mu values successfully. They observed that a very important approach to the analysis of data from inter-laboratory studies is to assess the structural parameter (Mu) and to provide a standard error for this estimate. The degree of Fe and other metal enrichment: DME (Fe) on its own is determined also with the relation in Equation 3.

$$DME\ (Fe) = \frac{\sum (M\ (Fe) - B\ (Fe)) \times 10}{B\ (Fe)} \quad (3)$$

Where M (Fe) is the measured concentration of iron in the automobile junk market and B (Fe) is the iron concentration in the background both in ppm.

RESULTS

Polycyclic aromatic hydrocarbon (PAH)

PAH was measured on samples of locations 1 and 2, and the background

Result analysis

At sample location 1, there was greater enrichment of Pb, Mn and Zn at lower depth 6-15 cm than the surface depth of 0-6 cm. Cu, Ni and Cr show similar level of enrichment at the two depths, while Cd is present only at a depth of 0-6 cm (Figure 5). At sample location 2, Cu, Mn, Pb, and Zn show greater enrichment with depth 6-15 cm. Ni and Cr show greater enrichment at surface depth of 0-6 cm, while Cd show similar enrichment at both depths (Figure 6).

At location 3, Cr, Zn, Pb and Cu show greater enrichment with depth 6-15 cm. Mn and Ni show similar enrichment, while Cd is more prominent at surface 0-6 cm depth (Figure 7). At location 4, all parameters measured show much greater enrichment pronounced at surface depth 0-6 cm (Figure 8). At location 5, all parameters measured show greater enrichment at lower depth 6-15 cm (Figure 9). At location 6 (background),

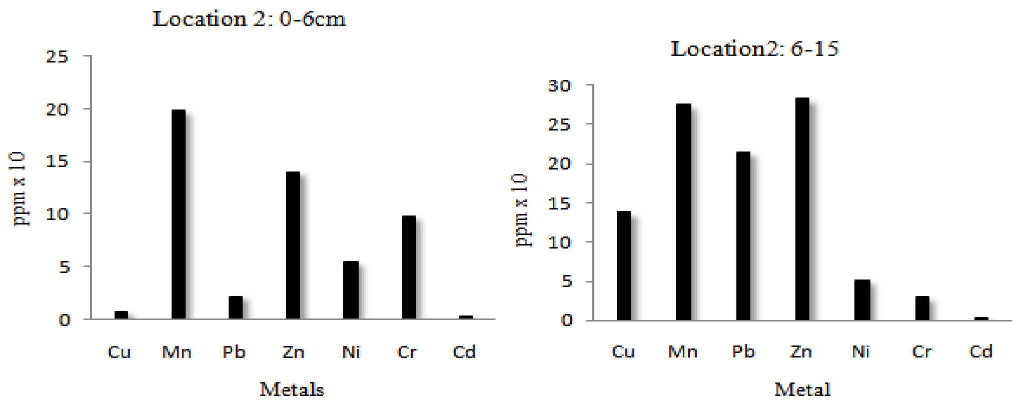

Figure 6. Trace metals concentration at location 2.

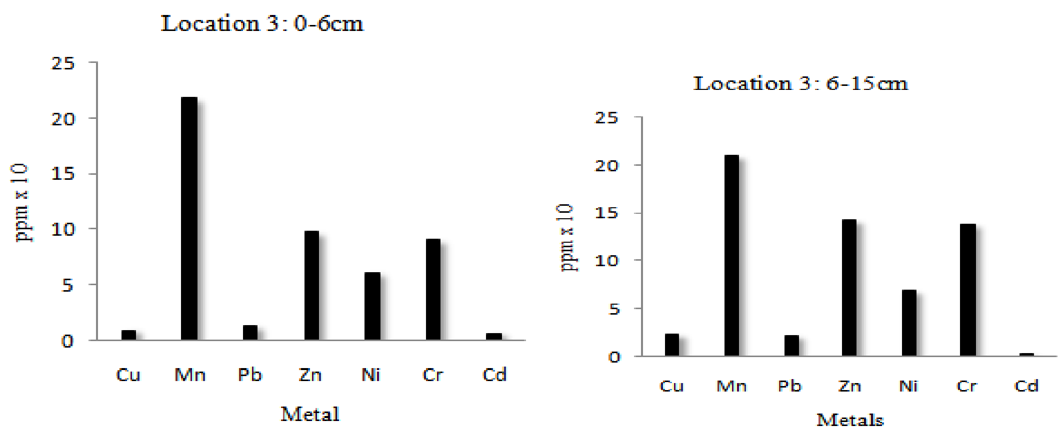

Figure 7. Trace metals concentration at location 3.

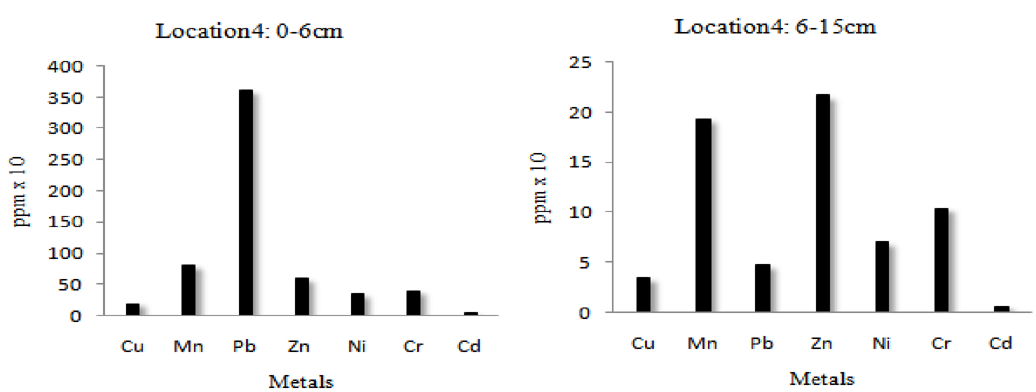

Figure 8. Trace metals concentration at location 4.

there were no traces of Pd and Cd at the two depths, while other parameters showed slightly greater affinity at lower depth 6-15 cm (Figure 10). Table 3 shows that Pb has the highest degree of metal enrichment (DME), pollution factor (Pf), and pollution index (Pi) followed by Cu, Cd, Zn, Cr, Mn, Ni, and Fe. For standard deviation,

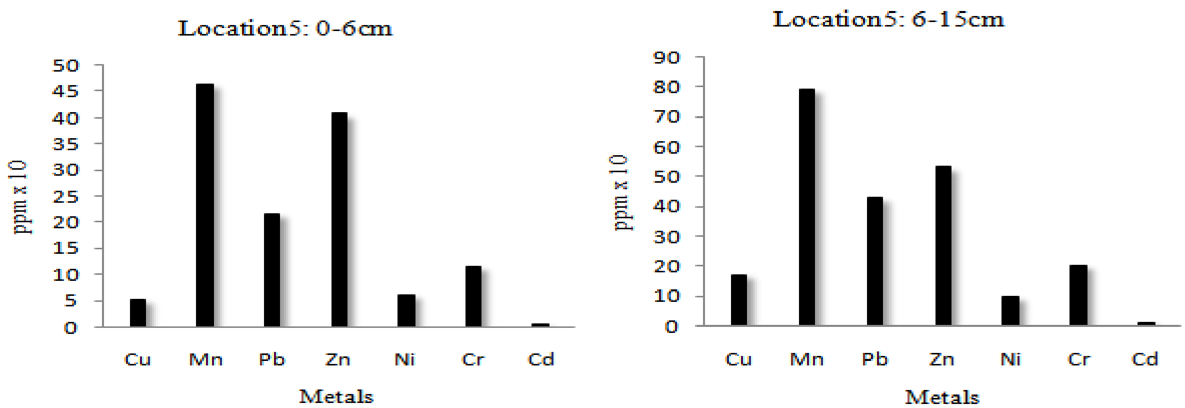

Figure 9. Trace metal concentration at location 5.

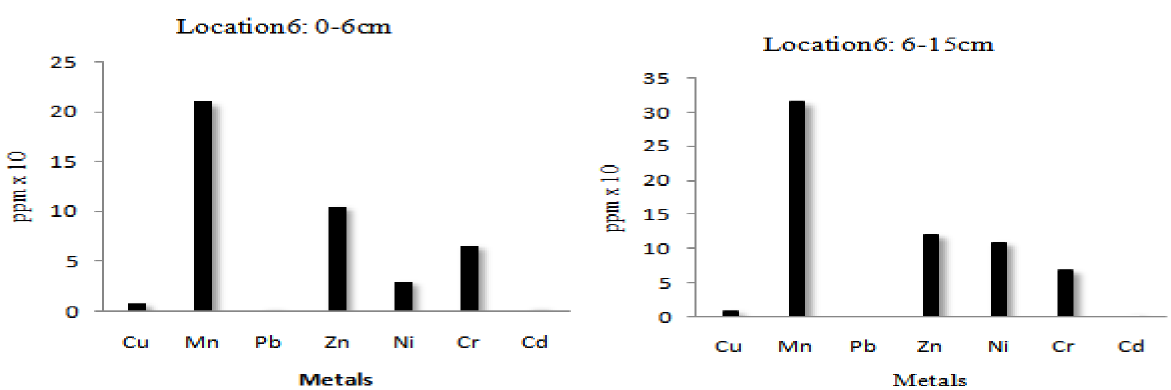

Figure 10. Trace metal concentration at location 6 (Background).

Fe has the highest, followed by Pb, Mn, Zn, Cr, Ni,Cu,and Cd. The agreement between DME, Pf, and Pi as seen in this analysis further justifies the use of the three parameters in pollution studies.

DISCUSSION

Table 2 shows the concentration (ppm) of the eight assessed trace metals in each sample layer of the Automobile Junk Market (AJM) and their background. The concentration of iron is isolated, while mean concentration, and degree of metal enrichment (DME) are contained. Mean concentration of trace metals in the 0-15 cm soil profile of the AJM is shown in Table 3 Computed pollution index (Pi), pollution factor (Pf), standard deviation (SD), and degree of metal enrichment (DME) per metal are well represented in the Table 4 as Pi, Pf, SD, and DME.

Results of this study show that metal concentration (ppm) above background value, in the AJM at 0-15cm of soil collectively ranges from: 9.79-59.25 for Zn; 19.4-81 for Mn; 0.74-19.82 for Cu; 0.3-4.47 for Cd; 2.97-39.7 for Cr; 1.34-362.8 for Pb and 5.16-34.58 for Ni. The order of abundance is: Pb> Cu> Zn> Mn> Cr> Ni> Cd for the AJM in Mgbuka Obosi. This is attributed to the availability of these metals in the spent engine and transmission oil usually disposed on the ground in the AJM. Other factors are metal mobility and characteristics of the soil.

The result shows that Pb is the major pollutants followed by Cu and Zn in the AJM. The three measurement values of great concern to the study are: concentration above background values (M-B), total concentration in the AJM (M) and background values (B), and the analysis shows excess concentration of lead at the AJM and a good assessment of the site situation. This primarily is attributed to engine recycling activity, corrosion, disposal of spent oil, dismantling operations, and improper handling and storage of vehicle components that contains lead. Mean pH in the AJM was obtained as 3.24 as against 7.0 background value.

It was also noticed that trace metals concentration (ppm) 0-15 cm of the AJM topsoil are well above the background values with Zn (24.06), Mn (19.80), Cu (9.41),

Table 3. Trace metals mean concentration, SD, Pi, Pf, DME values.

Parameter	Zn	Mn	Cu	Cd	Cr	Pb	Ni	Fe
Mean(AJM)	35.4	46.2	10.2	1.4	18.1	79.7	11.6	3633.2
Mean B'grd	11.3	26.4	0.8	0.3	6.7	0.1	7.0	2913.7
SD	19.9	27.4	8.4	1.5	12.2	127.6	9.4	302.3
Pi	3.1	1.75	12.3	4.5	2.7	613.2	1.7	1.3
Pf	0.7	0.4	0.9	0.8	0.6	1.0	0.4	0.2
DME (mgkg^{-1})	212.5	75.4	1133.7	345	168.3	6120.7	66.7	24.7

Table 4. Average trace metals concentration compared with EPA and Lindsay.

S/n	Metals	AJM (ppm)	Background (ppm)	AJM less background	EPA (2008) (ppm)	Lindsay (1979) (mgkg^{-1})
1	Zn	35.38	11.32	24.06	60	50
2	Mn	46.20	26.40	19.80	550	600
3	Cu	10.24	0.83	9.41	25	30
4	Cd	1.42	0.32	1.10	1.00	0.06
5	Cr	18.08	6.74	11.34	150	100
6	Pb	57.19*	0.005	57.19*	20	10
7	Ni	11.62	6.97	4.65	19	40
8	Fe	3633.20	2919.70	719.50	26000	38000

*Above EPA approved standard.

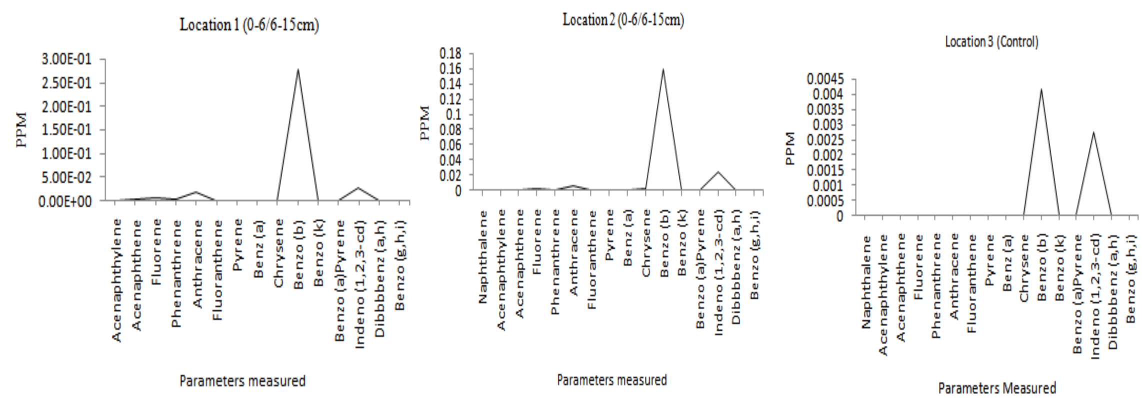

Figure 11. Graph of PAH distribution, (a) = locations 1-3; (b) = location 4-5; (c) Background.

Cd (1.10), Cr (11.34), Pb (57.19), Ni (4.65) and Fe (719.10). Only Pb was found in excess of international standards. Metal enrichment is in the order of Pb>Zn>Mn>Cr>Cu>Ni>Cd. Analysis of PAH found presence of fluorene and anthracene in the AJM soil as against the background soil (Figure 11). Chrysene, bonze, indeno, and dibbbenz were common. Trace metal concentration at the local Background (B) can be attributed mainly to local geology and the anthropogenic activities such as emissions from automobile exhausts. Disposing spent engine and transmission oil on the ground in AJM results in greater pollution potentials. It has greater contaminant binding capacity to the soil, making contaminants less mobile, and probably less bio-available in the 0-15cm profile.

In other words, bioavailability will vary with soil structure and organic matter content. The high concentration of lead, fluorene and anthracene, and the high level of acidity in the AJM soil suggest great impact on the nearby Idemili River.

Justification of result

The result of this study has proven that trace metal concentration is more prominent near surface or greater at lower surface depths. This agrees with the findings of Ximming et al. (2005) and Nwachukwu et al. (2010a), thus "heavy metal distribution is more superficial near surface with respect to depth'; in certain locations there could be enrichment of trace metals in the surface soil, whereas other locations could have enrichment in the lower subsurface depths". It has also shown that significant differences exists between the concentration of metals for both top and sub levels. It contradicts the work of Gilbert and Oladele (2009) on slag polluted soil due to different density of oil and slag, and their rate of infiltration to soil. One other point of note is the excess pH (average -3.24) of the soil in the Obosi AJM, as against the background value of 7.0. The implication of this is that the AJM soil is highly acidic. This level of acidity may be significant to insecurity of food products cultivated within and around the Obosi AJM.

Conclusion

This result compared with EPA standard requirement for agricultural soil suggests that only Pb is in excess, and well above limits. Analysis of the trace metal concentration indicates excess of lead in soil within and around AJMs. The pH result also indicate that the soil within and around the AJM is highly acidic. Operations therefore must be done in an environmentally friendly way to reduce toxicity of food products cultivated within and around AJMs.

Vegetables, tubers such as cassava cultivated within AJM environment may contain excess lead or become acidic, thereby being toxic. Frequent cases of food poison or insecurity occur, often leading to death or hospitalization of a household. These incidents take place without proper investigation of the causes; neither are there proper records of the incidents in Nigeria and in many other developing countries of the world.

RECOMMENDATIONS

The result of this work could serve as a baseline study for future monitoring of trace metals and PAH pollution in AJMs soils. Multidisciplinary study of the area should therefore be carried out to provide workable data for authenticity.

Converting and or building all AJMs and mechanic villages in Nigeria to modern AJMs with quality designs are vital, in order for all AJMs/mechanic villages to be environmentally friendly, and set the pace for other developing countries. Future studies shall be directed on the bioavailability of these trace metals in food crops cultivated within and around the AJM, and impact of the AJM to the nearby Idemili River. Farmers may be advised to stop cultivating vegetables and crops within and around AJMs, being contaminated land portions towards improving food security.

It is also important for a country like Nigeria to formulate effective trace metal pollution control measure which should cover legislation standards. There is urgent need to alert operators of automobile junk markets all over the world where old engines and transmissions are refurbished to be environmentally friendly. Set up environmental standards for the establishment and operation of automobile junk markets. There should be training and public awareness on establishment and operation of AJM, which similar to a mechanic village must be environmentally friendly.

ACKNOWLEDGEMENTS

We thank GEOPROBE International Consultants Limited Owerri, for instrumentation and logistics. Thanks go to the following staff of GEOPROBE for their field assistance: Maureen Ijeoma Nwachukwu, Chinedu Ohuawunwa, and Uche Nnorom.

REFERENCES

Abioye AP, Agamuthu P, Abdul Aziz AR (2012). Biodegradation of Used Motor Oil in Soil Using Organic Waste Amendments. Biotechnol. Res. Int. ID 587041, P. 8.

Adekola FA, Eletta OA (2007). A study of heavy metal pollution of Asia River, Ilorin, Nigeria: Trace metal monitoring and geochemistry. Environ. Monit. Assess. 125:157-163.

Asonye CC, Okolie NP, Okenwa EE, Iwuanyanwu UG (2007). Some physic-Chemical characteristics and heavy metal profiles of Nigerian Rivers, streams and waterways. Afr. J. Biotechnol. (5):617-624.

Crowder M (1992). Interlaboratory comparisons: Round robins with random effects. Appl. Stat. 41: 409-425.

Dioka CE, Orisakwe OE, Adeniyi FA, Meludu SC (2004). Liver and renal function tests in artisans occupationally exposed to lead in Mechanic Village in Nnewi. Niger. Int. J. Environ. Res. Public Health, 1(1):21-25.

Fleeger JW, Carmana W, Hong J, Nisbetb RM. (2003). Indirect stress of contaminants in aquatic ecosystem. Sci. Total Environ. 317(1-3):207-233.

Forstner U, Calmano W, Hong J, Kersten M (1998). Effects of redox variations on metal speciation. Waste Manage. Res. 4:95-104.

Gilbert UA, Oladele O (2009). Assessment of soil-pollution by slag from an automobile battery manufacturing plant in Nigeria. Afr. J. Environ. Sci. Tech. 3(9): 239-250

Horsfall M Jr, Horsfall MN, Spiff AL (1999). Speciation of heavy metals in water-tidal sediments of the Okirika River system, Rivers State, Niger. Bul. Chem. Soc. Ethiopian. 13(1):1-9.

Lindsay W (1979). Chemical Equilibrium in Soils. New York: John Wiley and Sons. (in: US EPA, 1987. A Compendium of Superfund Field Operations Methods. Exhibit 16-2. "The Content of Various Elements in Soils." pp. 169-266.

Mclean JE, Bledsoe BE (1992). Ground Water issue. Behaviour of metals in soils. US-EPA/540/s-92/018.* Utah Water Research Laboratory. pp 1-20.

McNeal JM, Balistrieri LS (1989). Geochemistry and occurrence of Selenium: an overview. Int.W.Jacobs (Ed), Selenium in agriculture and the environment. Am. Soc. Agron. Madison, WI. pp 1-13.

Nies DH (1999). Microbial heavy metal resistance. Appl. Microbiol. Biotechnol. 51:730-750.
Nwachukwu MA, Feng H, Alinnor J (2010a). Assessment of heavy metals pollution in soil and their implications within and around mechanic villages; Int. J. Env. Sci. Tech. 7(2):347-358
Nwachukwu MA, Feng H, Achilike K (2010b). Integrated study for automobile wastes management and environmentally friendly mechanic villages in the Imo River basin Nigeria; Afr. J. Environ. Sci. Tech. 4(4):234-249.
Nwachukwu MA, Feng H, Alinnor J (2011). Trace Metal Dispersion in Soil from Auto-Mechanic Village to Urban Residential Areas in Owerri, Nigeria. Elsevier- Science Direct; Procedia Environ. Sci. 4:310–322.
Ogboghodo IA, Iruaga EK, Osemwota IO, Chokor JU (2004). An assessment of the effects of crude oil pollution on soil properties, germination and growth of maize (Zea mays) using two crude types--Forcados light and Escravos light. Environ. Monit. Assess. (1-3):143-52.
Olajire AA, Imeokparia FE (2001). A study of the water quality of the Osun River. Environ Monitoring and Assess 69:17-28.
United States Environmental Protection Agency (USEPA) (2001). Human Exposure to Mercury report. available at http://www.epa.gov/hg/exposure.htm Extracted 06/11/2012. pp. 1-3.
Ximming W, Genxing P, Ping C (2005). The distribution and speciation of heavy metals in urban soils in Nanjing City. In: Urban dimensions of environ change, Science Press Inc., USA. pp. 25-33.