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Assessment of Soil in Automobile Repair Site for Heavy Metal Pollution

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A B S T R A C T

This study investigated the impact of automobile repair activities on the concentration of heavy metals in soil. The investigation of the impact of anthropogenic activity on soil heavy metals concentration is important because heavy metals are potentially toxic and anthropogenic activity is a major source of their release and pollution in the environment. In this study, the concentrations of Copper(Cu), Manganese(Mn), Chromium(Cr), Zinc(Zn), Nickel(Ni), Lead(Pb), Cobalt(Co), Arsenic(As) and Iron(Fe) were assessed in soil samples collected at depths of 0–20 cm using inductively coupled plasma–mass spectrometry (ICP-OES) in Bureau Veriats laboratory, Vancouver, Canada. The result showed the following average concentration values for the metals: 132. 5mg/kg for Cu, 7. 83mg/kg for As, 126. 67mg/kg for Cr, 32.67mg/kg for Co, 1285. 66mg/kg for Mn, 38.5mg/kg for Ni, 163mg/kg for Pb, 570. 17mg/kg for Zn and 139033mg/kg for Fe. The Average concentration of Pb, Zn, Co, Cr and Cu exceeded their uncontaminated soil levels, FAO permissible limits for soil and their levels in the crust. The contamination factor (CF) values indicated that there is high Pb and Zn contamination of the soil while Igeo values showed that the soil is moderately to strongly contaminated with Pb and Zn while Cu and As caused moderate contamination. The combined effect of all the metals, which was assessed, using pollution load index (PLI), resulted in the automobile repair site soil being highly polluted.

Keywords: *Heavy metals, Abakaliki soil, potentially toxic elements, trace metals, southeast Nigeria.*

1. Introduction

Metals and metalloids are inorganic components of the environment. Some are essential for plant and animal well being (Zn, Cu and Mn) while some are non-essential and toxic (Pb, As, Co and Ni), particularly to humans. These metals and metalloids, which subsequently, in this study, are referred to as heavy metals, are usually derived from natural and anthropogenic sources. Weathering of bedrocks is the major natural source while anthropogenic sources vary widely and include industrial activities, atmospheric deposition, agriculture, sewage and fossil fuel combustion. Soils are the major recipient of heavy metals because the weathering of bedrocks gives rise to soils and most human activities are carried out on soil.

Metals are not biodegradable, which result in their accumulation to elevated concentrations in soil. The accumulation of heavy metals can result in elevated concentration, potential pollution of the affected soil and human exposure with the associated health risk. The investigation of soils for heavy metals status is relevant for pollution prevention and control. A number of indices have been proposed to evaluate heavy metals status in environmental media, including contamination factor (CF), geoaccumulation index, pollution load index, and potential ecological risk index (RI) (Men et al. 2018). These indices were applied to ICP-OES generated data of Pb, Zn, Cu, Co, Mn, As, Ni, Cr and Fe in order to understand their status in the soil of an automobile repair site in Abakaliki, Ebonyi State, Nigeria.

2. Materials and methods

2.1. Study area

The study area, Abakaliki lies within latitudes $6^0 15^I$N and 6^0 20^IN and longitudes 8^0 05^I E and 8^0 10^I E in southeast Nigeria (fig 1). Its climate is tropical, characterized by high temperatures (average annual range of 24^0C to 33^0C . small temperature variations, high relative humidity and seasonal precipitation. The area has two major seasons of rainy and dry, influenced by the southwest maritime wind that blows from the Atlantic Ocean towards the north between March and October and the northeast trade wind that blows from the Sahara desert towards the south from November to February. The maritime wind is moisture laden, causing precipitation between March and October while the trade wind is cold, dry and prevails from November to February.

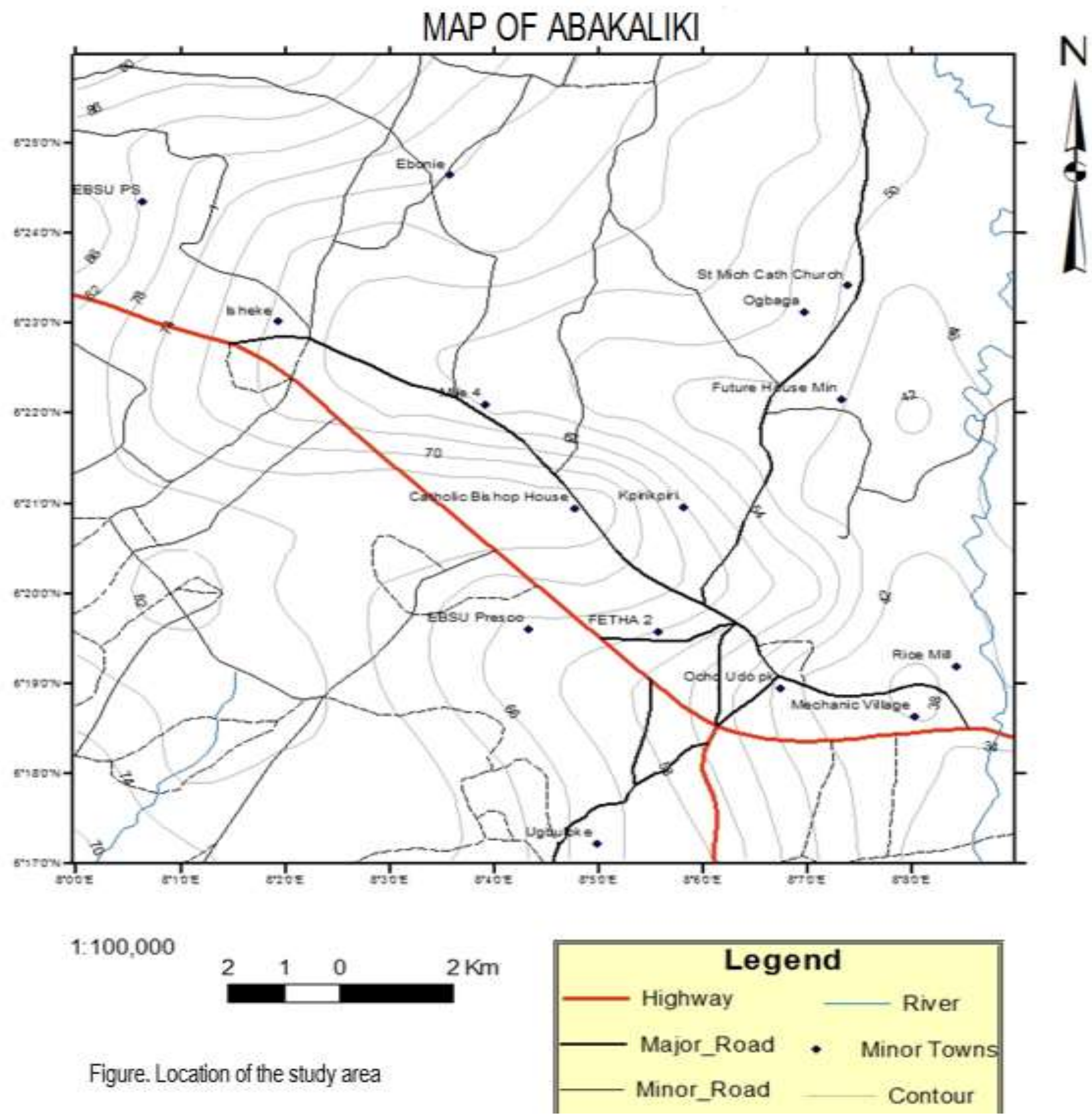

Figure. Location of the study area

The geology of the study area (Figure 2), is comprised of shale of Albian age (lower cretaceous), and localized occurrences of sandstone, siltstone and limestone intercalations (Ezepue, 1984).The shales are either greyish or reddish brown in colour depending on its content and degree of weathering. Topographically, the study area is undulating and drained by Ebonyi River, which is the main river and perennial streams (Iyi Udene and Iyiokwu). The natural vegetation of the study area is that of tropical rainforest that is being turned into derived savannah by human activities.

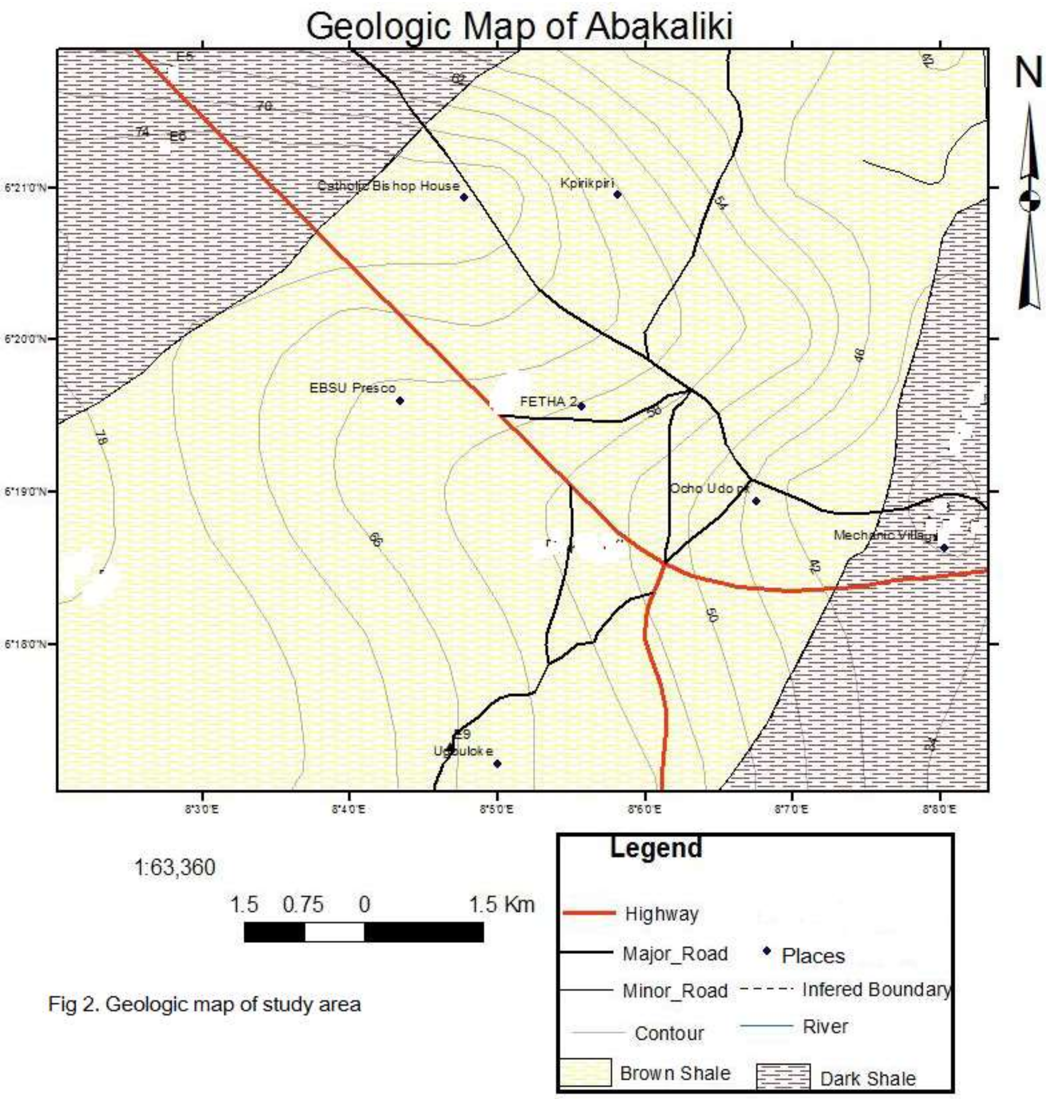

Fig 2. Geologic map of study area

2.2 Sample collection and analysis

Soil samples were collected in the investigated area at 0 –20 cm depths, using a shovel. The samples were collected at different points in the site to cover all the activities such as panel beating and painting. They were put in labelled plastic containers and were further, reduced to five samples, with each sample comprising three homogenized sub samples. This approach was to ensure the collection of samples that were representative enough. The ICP-OES analysis of the samples for Pb, Zn, Ni, Cu, Co, As, Mn Cr and Fe was done by Bureau Veritas laboratory, Vancouver, BC, Canada. The data were evaluated using the index of geo-accumulation (Igeo), contamination factor (CF), pollution load index (PLI) and comparison with published reference values.

Contamination factor (CF)

The contamination factor is also called the single-factor pollution index; The CF is the ratio obtained by dividing the concentration of each metal in the soil by the baseline or background value. The unpolluted earth's crustal concentration (Taylor and McLennan, 1995) was used as background concentration. Contamination factor can be used to assess the degree of contamination and evaluate the impact of soil quality on human life (Tomlinson, Wilson, Harris and Jeffrey, 1980). The contamination factor is calculated as shown in equation 1.

$$CF = \frac{Cm}{CB} \qquad (1)$$

Where C_M represents the measured concentration of the metal studied and C_B is the average geochemical background concentration of the metal in crust. The different classes of contamination factor by Kumar and Edward (2009) are: CF<1, low contamination; 1≤CF<3, moderate contamination; 3≤CF<6, considerable contamination; CF>6, very high contamination.

Geoaccumulation Index (Igeo)

Geoaccumulation index is the most popular index for pollution evaluation based on single heavy metals in soils (Men, et al., 2018). It is a quantitative measure of the extent of metal pollution in soil proposed by Muller (1969). This index (Igeo) of metal is calculated by computing the base 2 logarithm of the measured total concentration of the metal over its background concentration using the following mathematical relation:

$$Igeo = \log_2 \frac{CN}{1.5\ XBN} \qquad (2)$$

Where CN is the metal concentration in the soil samples, and BN is the geochemical background value of the metal. The constant (1.5) compensates for the natural variations in the background value of a given metal (lithologic variations) in the soils (Muller, 1969). The seven classes of Igeo as proposed by Müller (1969) are as follows: Igeo ≤ 0, uncontaminated (Class 0); 0 < Igeo ≤ 1, uncontaminated to moderately contaminated (Class 1); 1 < Igeo ≤ 2, moderately contaminated (Class 2); 2 < Igeo ≤ 3, moderately to heavily contaminated (Class 3);

Pollution load index (PLI)

The PLI assesses the mutual contamination effects of the metals and gives a generalized assessment on the level of soil contamination. PLI is calculated as the nth root of the number of multiplied contamination factor (CF) values (Tomlinson,1980) as shown in equation 3.

$$PLI = (CF_1 \times CF_2 \times CF_3 \ldots\ldots\ldots\ldots \times CF_N)^{1/N} \qquad ``(3)$$

Where, CF= contamination factor which represents the individual impact of each heavy metal on the soils and N = number of metals. Chen et al. (2005) classified the PLI as either low (PLI≤1), medium (1<PLI≤3) or high (PLI>3).

Potential ecological risk index (RI)

RI, proposed by Hakanson(1980), was used to evaluate the potential risk posed by heavy metal pollution to the environment. This method considers the concentration level of heavy metals in soil, comprehensively considers taking into consideration, the synergistic effect of multiple elements, toxicity, pollution degree, and the sensitivity of the environmental to heavy metal pollution. The RI was calculated from Ecological Risk Factor (Er) for a single metal using equation 4.

$$Er = TrxCF \qquad (4).$$

Where Er is the ecological risk for each metal, Tr represents the toxic response for the given metal which according to Håkanson (1980) are: Pb = 5, Zn = 1, Mn = 1, As= 10, Ni=5, Co=5 and Cu=5. CF is the contamination factor for each metal. The Potential Ecological Risk Index (RI) was calculated from the ecological risk (Er) as the sum of all risk factors for considered metals in soils (Equation 5)

$$RI = \sum_{i=1}^{n} Er \qquad (5).$$

Yang Guan, Chaofeng Shao and Meiting Ju(2014) classified potential ecological RI are as follows: RI ≤ 50, low risk; 50 < RI ≤ 100, moderate risk; 100 < RI ≤ 150, high risk; 150 < RI ≤ 200, very high risk; and RI > 200, extreme risk.

3. Results and Discussion

3.1 Results of Descriptive Statics of Study Variables

Table 1. Descriptive statistics of metals investigated

	Cu	Pb	Zn	Ni	Co	Mn	Fe	As	Cr
Max(mg/kg)	290	257	969	44	61	2391	172300	9	153
Min(mg/kg)	61	112	219	33	22	725	99700	6	90
Mean(mg/kg)	132.5	163	570.2	38.5	32.7	1285.7	139033.3	7.8	126.7
STDEV	85.7	62.4	285.5	4.41588	15.8	638.9	27566	1.2	26.6
Skewness	1.5	0.9	0.31	1.08E-16	1.5	1.3	-0.3	-0.7	-0.4
Kurtosis	2.4	-1.3	-1.2	-2.2	1.4	0.7	-1.4	-0.4	-1.9
CV (%)	64.7	38.3	50.1	11.46982	48.4	49.7	19.8	14.9	21.9

Table.1 displayed maximum, minimum, mean, standard deviation, skewness, kurtosis and coefficient of variation of the heavy metals investigated. The metals were found to occur in the following range in Mg/Kg: Cu (61 to 290), Co (22 to 61), Pb (112 to 157),Fe(725 to 172300), Mn (725 to 2391), Zn (219 to 969), Ni (33 to 44) and As (6 to 9). The average concentrations, in mg/kg, of heavy metals in the mechanic site soil were Cr(90 to 153, As(7.8), Co(32.67), Cu(132.5), Fe(139033.33), Mn(1285.67), Ni(38.5), Pb(163), Cr(126.67) and Zn(570.17). The concentrations of these metals in the soil follow the order: Fe>Mn>Zn>Pb>Cu>Cr>Ni>Co>As, with Fe as the most abundant and As concentration, the lowest. The skewness and kurtosis results showed that Fe, As and Cr have negative biases while Zn is approximately normally distribution and Cu, positively skewed. The coefficient of variation (CV) showed that Cu concentration varied the most in the soil, indicating that its concentration is the most influenced by the activities in the site while the concentration of Ni, having the lowest CV among the metals investigated, is the least influenced. How these metals compare with other reference standards are shown in table 2 and figure 3.

Table 2. Average crust and FAO target values of investigated metals

	Pb	Zn	Cr	Ni	Co	Cu	As
study Mean	163	570.1667	126.6667	38.5	32.66667	132.5	7.8
Who/FAO	50	200	100	50	20	100	20
Average crust	17	71	85	44	17	25	1.5

Average crust (Taylor and McLennan, 1995), FAO, (2004)

Comparing the metals with other standards, showed that the average concentration of Pb, is higher than the FAO permissible limit of 50mg/Kg for soil (Table 2), its background value (16Mg/Kg) and the uncontaminated soil values of 34Mg/Kg, given by Nriagu(1994). Pb is usually released through anthropogenic activities and due to its immobility and affinity for organic matter, accumulates in the upper layer of soil. This may explain the observed elevated concentration of Pb in the study area.

The concentration of Zn is higher than its normal range in soil (10-100 Mg/Kg) and its average of 70mg/kg in crust quoted by Kabatia -pendias, (2011). Zn average concentration (570. 17mg/kg) in this study is also higher than uncontaminated soil average values (50-55mg/kg) given by Alloway, (1995) and FAO target value of 300Mg/Kg.

Copper average concentration of 132.5Mg/Kg, is higher than the crustal value, its average range in uncontaminated soil (13 -24 Mg/Kg) documented by Kabata Pendias and Pendias (2001) and FAO target value of 100Mg/Kg. Ni average concentration was found to be within its average concentration in surface soils worldwide (20 to 40 Mg/kg) according to Alloway (1995) and within the target value (50Mg/kg) stipulated by FAO.

The average concentration of Co was found to be higher than its average concentration in soils worldwide (10 -15 Mg/Kg) and also the FAO target value of 20Mg/Kg. Arsenic average concentration is within FAO target limit (20mg/kg) but higher than average crust(1.5mg/kg. The average value of Mn(1285. 67Mk/Kg) recorded in this study is higher than 872.54Mg/Kg observed for India soil by Kumar(2009) and higher than 155. 71Mk/Kg average recorded by by Sikakwe(2017) in Oban Massif soil, Nigeria. Fe, which is the most abundant of the metals studied, is approximately 4 times its concentration in the crust but within average shale value, which is the soil bedrock. Cr is higher than FAO target (100mg/kg) and its average crust (85mg/kg). How the metals investigated in this study compare with other standards is illustrated in figure 3.

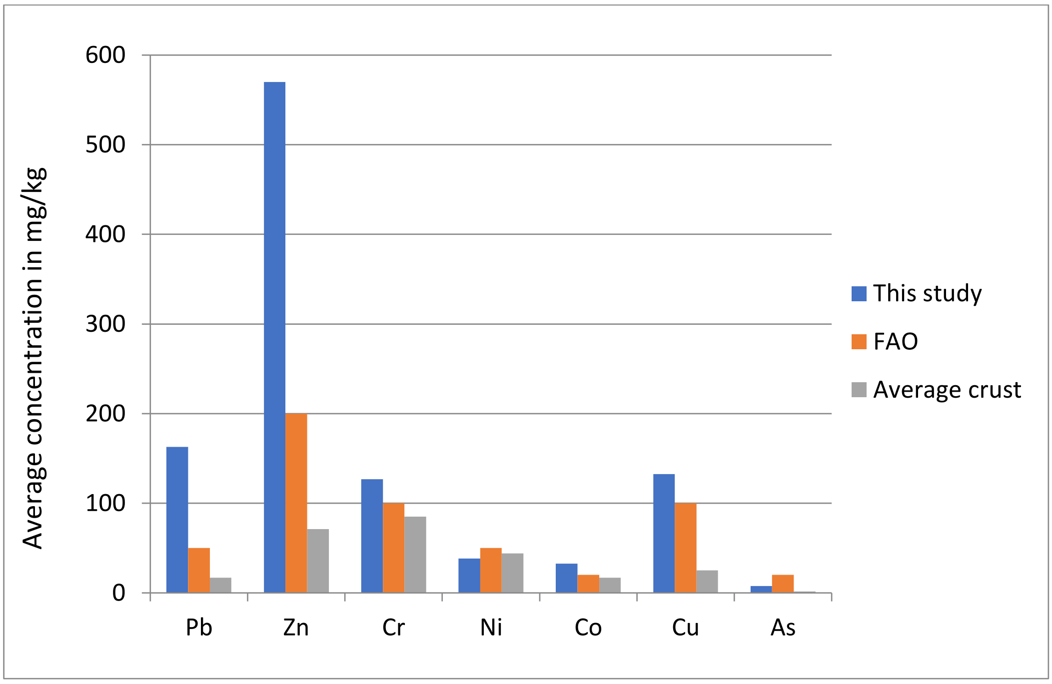

Figure 3. Levels of metals in this study compared with other standards

Table 3. Contamination indiced of metals studied

	CF	Igeo
Cu	5.3	1.601729908
Pb	10.1875	2.68262905
Zn	8.030516432	2.248754049
Ni	0.734507042	-1.054316648
Co	1.921568627	0.23936411
As	5.222222222	1.78543624
Cr	1.490196078	-0.037885838
Mn	2.142777778	0.38480894
Fe	3.152480952	-0.365867726
	PLI 4.21	

Table 3 displayed the CF, Igeo and PLI values of heavy metals of study. The result showed that the mean CF of Ni is less than 1, which indicated low contamination while moderate contamination is caused by Cr, Co and Mn (CFs less than 3). Fe, As and Cu caused considerable contamination ($3 \leq CF < 6$) while there is very high Pb and Zn contamination of the soil. Igeo values showed that Cu, As, Zn and Pb caused moderate to strong contamination of the soil while the combined effect of these metals in the soil, which was assessed using PLI, indicated that the automobile repair site soil is highly polluted.

Conclusion

The result showed that there is release of heavy metals by automobile repair activities, which led to the soil being highly polluted. This can pose risk to the wider environment in the long term, thereby requiring control.

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