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APPLICATION OF MULTIVARIATE ANALYSIS IN THE ASSESSMENT OF TRACE METAL POLLUTION IN ABANDONED ASPHALT AND BITUMEN PLANTS IN IDU, URUAN LOCAL GOVERNMENT AREA OF AKWA IBOM STATE, NIGERIA

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ABSTRACT

The study evaluated seven trace metals concentration and pollution of the soil of the abandoned Asphalt and Bitumen plant site in Idu in Uruan Local Government Area of Akwa Ibom State, Nigeria. Multivariate statistical approaches were used to evaluate sources of the trace metal concentration in soil samples assessed. Results obtained indicated three components as a major source of trace metal load in the soil of the study site with Eigenvalue greater than one and significant total variance of 82.31%. Factor 1 contributed 40.74% of total variance with significant positive loading on Fe, Mn, Cu and Cr. This represents the impact of industrial activities and effluent on the quality of the studied soil. Factor 2 contributed 26.99% of the total variance with strong positive loading on Pb and Ni. This represents the impact of industrial effluent and pedogenic materials on the studied soil quality. Factor 3 contributed 14.84% of the total variance with strong positive loading on Fe and Zn which represents the impact of natural processes on the quality of the studied soil. Results showed that the soil of the study site in Idu, Uruan Local Government Area is affected by the activities of Asphalt and Bitumen production conducted and abandoned over the years. As such the site is not totally free from trace metal pollution load. It is therefore not quite safe and suitable for agricultural activities in view of the effect of such metals in the soil and plants of the study location. It is also obvious that the trace metal assessed in the study site may affect the edible plant species cultivated within the study location in view of their bioaccumulation and translocation factors of such plant species. Therefore, there is that tendency of the trace metals to enter the food chain leading to chronic or acute metal toxicity in humans

KEYWORDS: *Principal Component Analysis (PCA), Cluster Analysis, Randomized Complete Block Design (RCBD), Idu, Uruan, Asphalt and Bitumen*

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INTRODUCTION

As mentioned by Akubugwo*et al.* (2016) the use of Greenfield environment for industrial activities over the years has led to remarkable destructions of the virgin land suitable for agricultural activities. This to a greater extent also has affected soil productivity as well as crop growth and development. Akubugwo and Duru (2011) reported that the effect of industrial activities couple with effluent generated and introduced into the immediate soil environment also affected microbial activities. Chen, and Zheng (1999) mentioned that the nutrient element also needed for plants growth and development are also being eroded as results of unproductive industrial activities being undertaken in Greenland environment.

Dutta*et al.* (2007) stated that the introduction of organic and inorganic elements generated in view of industrial development also affected the soil fertility. Accordingly, as stated by Edet and Nganye (2014) the soil accumulated these substances since the soil act as a buffer to these organic and inorganic elements released directly from the effluent into the soil matrix. Chinenyeze and Ekene(2015) further stated that the tendency for these elements to be transported through the soil matrix is obvious depending on the P^H, structure of the soil as well as the chemical state of the elements being released and produced into the soil environment.

Eze*et al.* (2014) mentioned that the introduction of these inorganic substances such as trace metals could be detrimental since there is that tendency of the trace metal to enter the food chain. Trace metal toxicity according to Ekpeyong and Udofia(2015) is obvious in industrial areas depending on the periods and the level of exposure. According to Etesin*et al.* (2013) chronic or acute exposure toxicity occur over time depending on the surface area of exposure. As mentioned Ewa*et al.* (2011) trace metals are non-biodegradable as such could remain stable over the years in trace quantity leading to heavy accumulation which invariably is detrimental to plants as well as human growths and development. Kogbara*et al.* (2015) revealed that the tendency of the trace metal to enter the food chain depends on the bioaccumulation and translocation factors of some plant species in the affected area. The health effect becomes obvious especially when the edible parts of the plants are affected since most of the people in the rural areas use most of these plants as medicinal purposes.

Khan*et al.* (2013) mentioned the need for the assessment of trace metal pollution in areas used for industrial activities regularly to ensure the baseline environmental indicators are not altered. Timely and regular assessment of such industrial development according to Moses and Uwah (2015) prevented the extent of environmental consequences being experienced in industrial areas. As reported by Nyake and Osuji(2016) such development also assisted in proper remediation as well as in the enforcement of appropriate environmental laws and regulations. Proper and sustainable enforcement of regulatory laws to further prevents damage on land Air and water.

As mentioned by Nriagu (1989) use of Greenland for asphalt and bitumen plants development and production recently has become new development in rural areas. Over the years this plant had been used and abandoned after road construction with no post impact assessment conducted to ascertain the effect of such activities on the soils and plants within the area (Osuocha*et al.*2015). Though such plants have been used and abandoned, there is that tendency of agricultural activities such as crop production, cultivation, and development within the rural areas being affected areas in view of negative consequences caused by such industrial activities within the environment

Accordingly, in view of the composition and structural integrity of the asphalt and bitumen used for road construction, there is a tendency of trace metals being introduced into the soil environment. This development exposes humans to a severe public health crisis. Hence post impact evaluation of the abandoned asphalt and bitumen site should be conducted to as certain the extent of damage done to the affected environment. In view of the development, this study was undertaken to as certain the extent of the relative effect rendered by such industrial development in the study area.

Therefore, to ensure effective evaluation and assessment of the associated effect, the study employed a multivariate method of assessment to ascertain the source of pollution and the extent of damage done to the affected environment. Multivariate method of assessment employed Principal Component Analysis (PCA), Cluster analysis and regression correlation coefficient to ascertain the damage done in the study soil to ensure effective evaluation of the pollution load (Facchinelli*et al.*2001). The outcome which will be very useful in the management and control of trace metal pollution in the affected area. And in providing remedial measures so as to prevents severe environmental degradation in the study site in Idu community in Uruan Local Government Area of Akwa Ibom State, Nigeria.

The Study Area

Idu is one of the villages in Uruan local Government Area of Akwa Ibom State, Nigeria as shown in Figure 1. Idu is in the Central Uraun of Akwa Ibom Ibom. It is also headquarter of Uruan Local Government Area. The area has abundant natural resources such as crude oil and gas. Idu also has forest resources such as timber. Industrial development within the study area is located mainly in Idu Uruan being headquarter of the Local Government Area (LGA). The study area is bounded by the east by Uyo Local Government Area and north by Abesikpo Asutan Local Government Area. Typically, the main occupation in the study area is fishing and peasant farming. The area has good road network leading to the outstanding recreational facility in Nwaniba with good landscape facility developed for the recreational facility by the Akwa Ibom State Government. The rainfall within the study area is all year round and more severe in July and August.

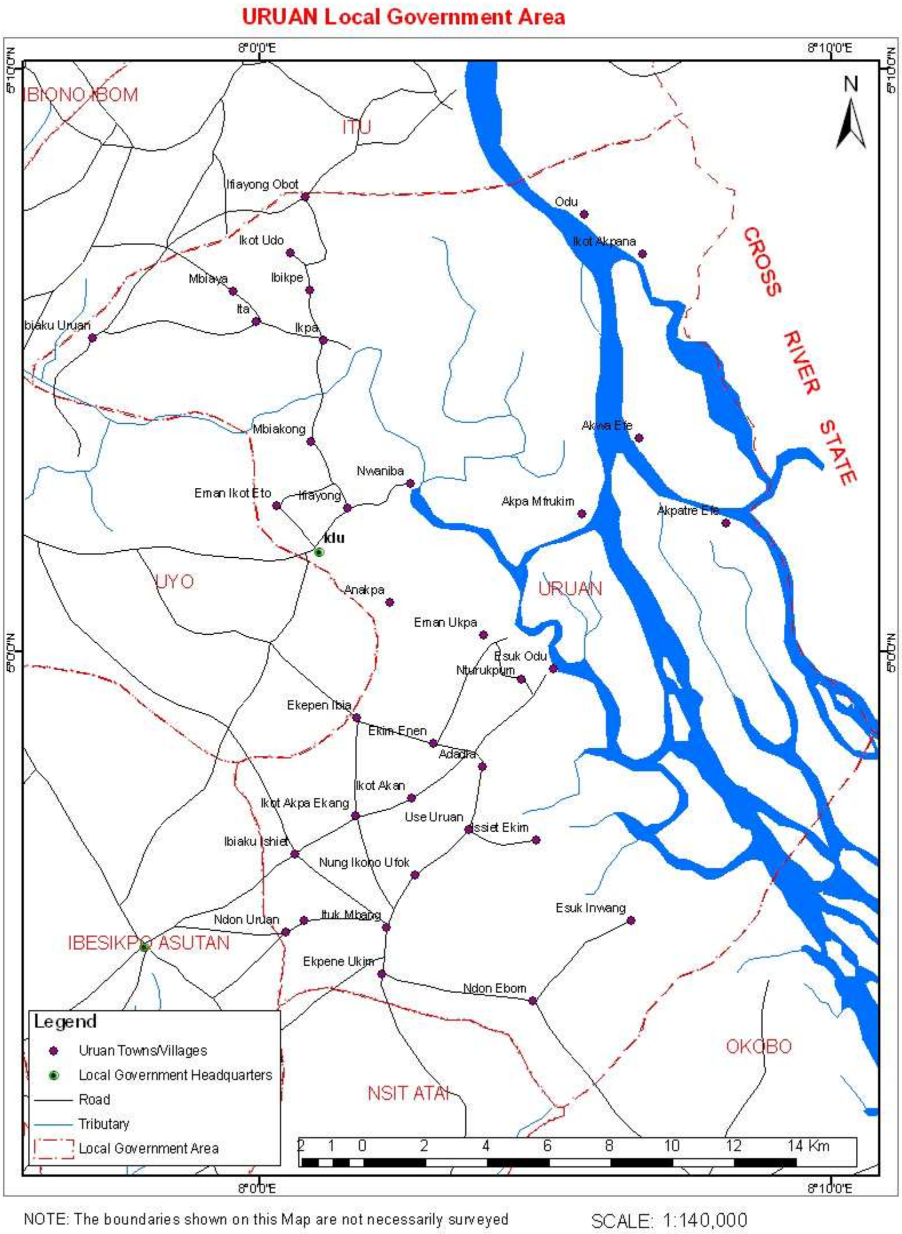

Figure1: Map of Uruan Showing the Study Area

Source: Ministry of Land and Survey, Akwa Ibom State, Nigeria

Experimental Design

2x6 factorial experiment in randomized complete block sampling design (RCBSD) was utilized in the collected of soil samples from two soil depths from the study locations. In this case, five areas affected by the asphalt and bitumen production in the study area were selected and three area randomly selected from the five area randomly selected. Then soil samples were collected in triplicate from the selected site in the study area using soil augur for this study

Soil Sampling and Laboratory Analysis

The soil samples collected in triplicate from the three areas selected randomly for this study were treated prior to analysis. In this case, One gram of the oven-dried ground soils previously washed with nitric acid and distilled water was placed in 100cm3 kjedahl digestion flask (Osuji and Nwoye,2007). The samples were subjected to wet acid digestion reacted with 2cm3 of 60% perchloric acid ($HClO_4$), 10cm3concentrated nitric acid (HNO_3) and 1.0 cm3 concentrated sulphuric acid (H_2SO4)(AOAC, 1990). The mixture was swirled gently and slowly at moderate heat on the digester, under a fume hood. The heating continuous until dense white fumes appeared which was then digested for 15 min, set aside to cool and diluted with distilled water. The mixture was filtered through the What man filter paper into a 100cm3 volumetric flask, diluted to mark (Osuji and Nwoye,2007). The blank and the samples were digested in the same way. The concentration of the metals present in each soil was obtained using HACH3900 model Spectrophotometer using ten 10mls of digested soil solution with the relative powder pillows. Dilution factors applied when the concentration was noticed high. Final results multiplied with the dilution factor to obtained the final reading in mg/l of the total sample used

Statistical Analysis

Descriptive and multivariate agglomerate hierarchal cluster analysis was employed to analyze the trace metal properties of the soil samples collected from designated study sites. The similarities between trace metals in the soil samples measured through the application of cluster and correlation coefficient statistical analyses. The sources of trace metals determined using the principal components analysis. The level of the correlation coefficient between trace metals in soil measured at p<0,05, p<0.01 to determine the relationship between the trace metals in the soils of the study sites according to Alkarkhi*et al.* (2009).

RESULTS AND DISCUSSIONS

Descriptive Statistics of Trace Metal Concentration in Study Location

The descriptive statistics of the soil of the study sites is as shown in Table 1 below. Iron (Fe) concentration of the study site was higher when compared with other trace metals in the study location. The result showed that the Fe content of the studied soil samples varied between 21.07mg/l to 34.87 mg/l with a mean of 25.37mg/l ±4.05 mg/l with a higher variance of 16.38mg/l which contributed to the standard deviation recorded (Onojake*et al.*2011). Table 1 also showed that the Zinc (Zn) concentration of study site varied between 9.28mg/l and 12.67 mg/l with a mean concentration of 10.65 ±1.04mg/indicated that Zn concentration in the study soil sample was lower than Iron (Fe) concentration obtained in the soil samples tested at the asphalt and bitumen sites. The Lead (Pb) concentration of the studied soil sample varied between 0.16mg/l to 0,67mg/l with mean value of 2.27±1.13mg/. Comparatively the standard deviation of Pb concentration in the study site was however lower than those of Fe and Zn due to the low variability of Pb concentration in the study soil sample. Table 1 also shows the Nickel concentration of the study soil samples. Table 1 showed that the nickel (Ni) concentration varied between 0.11m/l and 0.25mg/l with mean concentration of 0.15±0.044mg/ accordingly the concentration of manganese (Mn) in the study soil sample varied between 1.11mg to 2,34mg/l with a mean concentration of 1.55±0.35. Table 1 also shows that the concentration of copper in the study soil sample varied between 1.45mg/l to 4.57mg/l with mean concentration of 2.58±0.96mg/.Copper (Cu) concentration varied between 0.11mg/l to 0.23mg/l with a mean of 0.17±04mg/l. The differences in the concentration of the trace metal in the study site show the variability existed between the trace metals in the study soil sample and the relationship that existed between the trace metals in the soil of the study location.

Table 1: Descriptive Statistics of Study location

Descriptive Statistic of soil sample in mg/l						
	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Fe	13.70	21.17	34.87	25.3656	4.04854	16.391
Zn	3.39	9.28	12.67	10.6467	1.03626	1.074
Pb	3.51	.16	0.67	2.2744	1.12611	1.268
Ni	.14	.11	.25	.1533	.04416	.002
Mn	1.23	1.11	2.34	1.5511	.35353	.125
Cu	3.12	1.45	4.57	2.5856	.95782	.917
Cr	.12	.11	.23	.1722	.03528	.001

Correlation Coefficient

Table 2 also shows the Pearson correlation coefficient of the study soil samples. As showed in the Table2 correlation coefficient between the trace metals in the study soil samples observed showed the significant and insignificant relationship between the metals content in the study soil samples. As shown in Table 2Fe correlated positively but insignificantly with Mn and Cr at p<0.05 with r values=0.489 and.580 respectively. Indicating that an increase in the concentration of Fe in the study soil sample may influence the concentration of Mn and Cr in the study soil samples. This feature is in line with that obtained by (Okoro*et al.*2011) on the assessment of crude oil impacted soil as a result of industrial activities over the years, However, Zn showed negative, but significant relationship with Cu and Cr at p<0.05 with r values=-.692 and -.671 respectivelyindicating that an increase in Zn may lead to relatively increase in the concentration of Cu and Cr in the study soil samples. This feature however, agrees with the findings of (Osujiand Onojake, 2006). Table 2 also showed that Pb correlated insignificantly with the metals tested in the study soil samples.Indicating that an increase in Pb concentration may not cause significant increase in the concentration of trace metal in the study site. Nickel (Ni) however showed negative but insignificant correlation with Mn and Cr at p<0.05 with r values=- 0.520 and – 0.439 respectively. Indicating that an increase in the concentration of Nickel (Ni) may lead to corresponding decrease in the concentration of Mn and Cr in the study location. However, the correlation coefficient between Cu and Cr was positively insignificantly at p<0.05 with r value =0. 445. Therefore an increase in the concentration of Cu in the study location may not cause a relative increase in the concentration of Cr. Other trace metal the exhibited insignificant relationship with other metals in the study location, but however should relationship that existed between the trace metals in the soil of the study site.

Pearson Correlation Coefficient of the Study Soil Sample

Table 2: Correlation Coefficient of Soil Sample

mg/l of Trace Metals Concentration							
Metals	Fe	Zn	Pb	Ni	Mn	Cu	Cr
Fe	1						
Zn	-.131	1					
Pb	.131	-.356	1				
Ni	-.102	.068	.571	1			
Mn	.489	-.083	.073	-.520	1		
Cu	.375	-.692*	.370	-.016	.153	1	.
Cr	.580	-.671*	.041	-.439	.393	.445	1
*. Correlation is significant at the 0.05 level (2-tailed).							

Principal Component Analysis (PCA)

The principal component analysis used for the identification of factors responsible for the accumulation of these metals in studied soil revealed three major factors with Eigenvalues more than one and a total variance of 82.31% (Table 3). Factor 1 contributed 40.74% of the total variance with significant positive loading on Fe,Mn,Cu and Cr (Table 4). This represents impact of industrial activities and effluent on the quality of studied soil (Onweremadu*et al.*2007). Factor 2 contributed 26.99% of the total variance with strong positive loading on Pb and Ni. This represents the impact of industrial effluents and pedogenic materials on the studied soil quality (Oderinde,,1984). Factor 3 contributed 14.84% of the total variance with strong positive loading on Fe and Zn which represents the impact of natural processes on the quality of studied surface soil (Chen and Zheng. 1999).

Table 3: Total Variance of Principal Component Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.833	40.474	40.474	2.833	40.474	40.474	2.240	32.006	32.006
2	1.889	26.992	67.466	1.889	26.992	67.466	1.817	25.951	57.957
3	1.039	14.843	82.308	1.039	14.843	82.308	1.705	24.351	82.308
4	.624	8.911	91.219						
5	.435	6.209	97.428						
6	.135	1.927	99.355						
7	.045	.645	100.000						

Table 4: Total Trace Metal Components Extracted

	1	2	3
Fe	.672	-.115	.552
Zn	-.738	-.379	.491
Pb	.270	.795	.358
Ni	-.359	.838	.273
Mn	.574	-.458	.478
Cu	.734	.400	-.182
Cr	.876	-.168	-.170

Cluster Analysis

The pair-wise association among trace metals in Idu abandoned asphalt and bitumen site is also shown in cluster analysis in Figure 1. Cluster analysis resulted in two main clusters namely: (i) the one between Ni, Cr, Pb, Mn and Zn (ii) the one with Fe. This revealed the common relationship among the studied trace metals in the studied soil sample. Figure 2 also showed that Ni, Cr, Pb, Cu and Zn form a lithogenic relationship with Fe. Indicating that Ni, Cr, Pb,Cu and Zn are contaminants that originated from mixed anthropogenic and lithogenic sources in view of the relationship of these metals with Fe. This feature is in line with the findings of (Oyem and Oyem, 2013).

A plot of the major components in Principal Component Analysis (PCA) resulted in figure 2 with two major components (Component 1 showed strong positive correlation with Ni, Cr, Pb,Cu and Mn. This is consistent with factor one in Principal Component Analysis (PCA) assessment of trace metals in soil sample assessed at the asphalt and bitumen site in Idu. Component 2 correlated significantly and positively with Pb and Ni representing factor 2. Component 3 showed strong loading for Fe which represents factor 3. These features are in line with the findings of (Ogbonnae *et al.*2009).

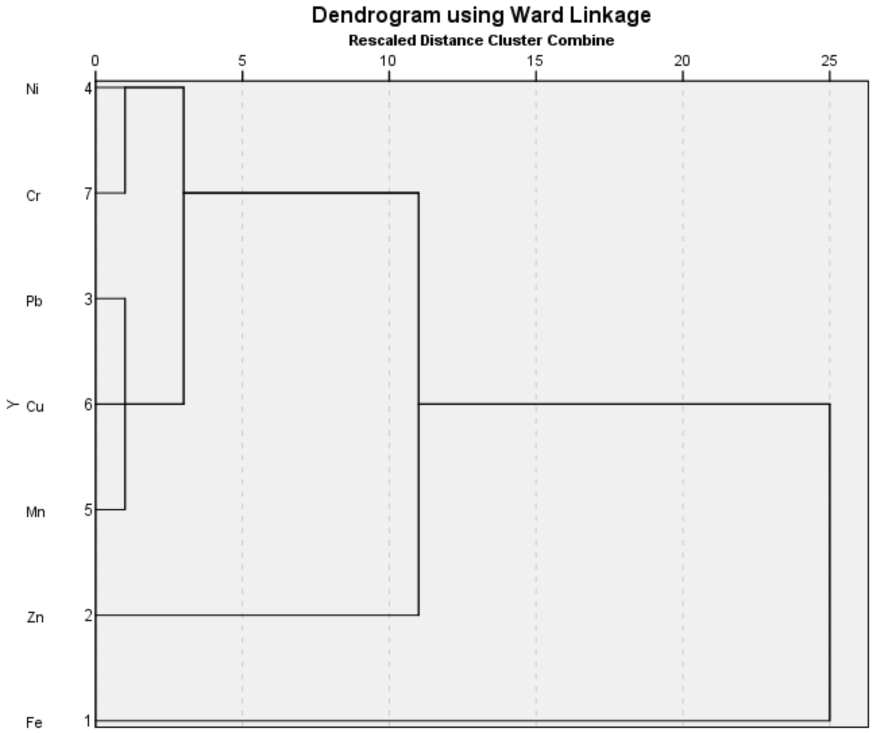

Figure 1: Hierarchical Cluster of Trace Metal in Study Soil Sample

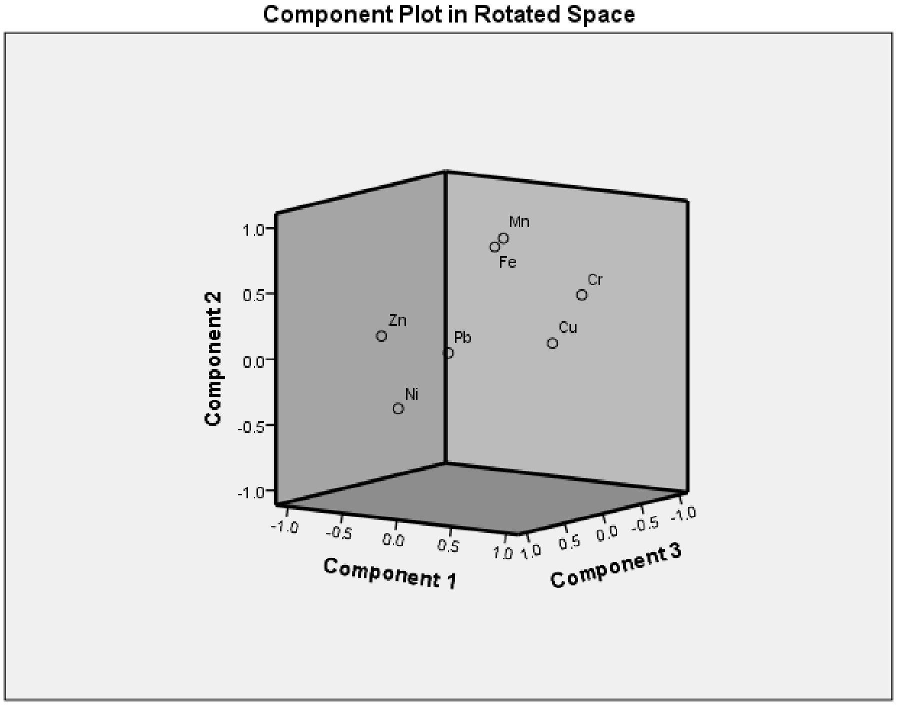

Figure 2: Plot of the Principal Component of Trace Metal in Study Location

CONCLUSIONS AND RECOMMENDATIONS

The trend of the trace metal pollution noticed at the asphalt and bitumen production site abandoned over the years has shown that relationship existed between the trace metal and the soil environment (Onweremadu*et al.*2007). The study revealed that anthropogenic and lithogenic activities contributed significantly to the trace metal load in the soil of the study site. This feature is in line with that obtained by (Roza and Singh,2010). Therefore, in view of this relationship, the pollution load experienced within the asphalt and bitumen plant abandoned site could be associated with mixed activities as results of anthropogenic and lithogenic relationship existed between the metals in the study site

Therefore, to further reduce the effect of soil metal accumulation. There are needs to remediate the soil environment to further prevent the trace metal from entering the food chain. Cultivation of edible vegetable plant species should not be conducted in the study site to prevent metal toxicity in human due to bioaccumulation and translocation factors associated with such plants. it is also important to ascertain the bioaccumulation and translocation factors of the edible plant species cultivated and widely consumed in the study site to ensure that such plants are safe and suitable for human consumption.

It is obvious that the underground water quality could be affected due to the lithogenic relationship between these metals and iron (Fe) content of the study site. Hence public water within the study site produced for human consumption and other domestic use should be tested for trace metal concentration to prevent trace metal toxicity (Osuji and Onojake, 2004).

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