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Assessment of Geo-Accumulation Index (I_{geo}) In Soil Samples of Fika Agrarian Community of Yobe State, Nigeria, Using Mp-Aes Analytical Technique

Muhammad Hussaini
Lecturer, Department of Physics, Umar Suleiman College of Education Gashua, Yobe State, Nigeria
Dr. Abubakar Danjuma Bajoga
Senior Lecturer, Department of Physics, Gombe State University Gombe, Nigeria
Mohammed Mustapha
Lecturer, Department of Physics, Umar Suleiman College of Education Gashua, Yobe State, Nigeria
Dr. Umar Sa'ad Aliyu
Lecturer, Department of Physics, Federal University Lafia, Nasarawa State, Nigeria

Abstract:
This study examined the concentration level and geo-accumulation index of trace element in composite soil samples in Fika local government area of Yobe, Nigeria. Soil samples from ten locations were collected at a depth of 0 to 20 cm using soil auger in the study area through purposive sampling technique and global Positioning System (GPS) device was used to mark the sample locations and elevations above sea level. Microwave Plasma Atomic Emission Spectrophotometer (MP-AES) was used to determine the concentrations of trace elements in the study area. From the data obtained elemental concentration (EC) and geo-accumulation index (I_{geo}) of each element was determined. Based on the result obtained, the mean elemental concentration in the study area was of the order of Pb(81.585 ± 25.591) > Fe(53.907 ± 4.593) > Al(3.941 ± 2.595) > Mn(2.311 ± 0.291) > Zn(0.500 ± 0.167) > Cr(0.151 ± 0.015) > Co(0.002 ± 0.000) > Cd(0.001 ± 0.00) in ppm respectively. Of all the trace elements detected, only Pb in FKA_1 was found to be above the International benchmark. Moreover, strong I_{geo} value correlations were obtained between (Zn – Pb) and (Al - Fe) at 0.5 significance level. The result further revealed that all the mean I_{geo} values of trace element were < 0 which imply that all the soil samples analyzed were uncontaminated and unpolluted. The study recommends that there is need to extend the scope of the study to cover radiological contaminants in soil, plants and river sediments in the study area so as to obtain a composite baseline data.

Keywords: *Trace element, fika, geo accumulation index, microwave-plasma atomic emission spectroscopy, soil contamination*

1. Introduction

Soil is a composite system which consists of organic and inorganic matter that directly or indirectly supports plant and animal life and is a crucial component of our rural and urban environments (Emanuel, 2015). Trace elements are natural constituents of soil which come from rocks and soils through the processes of erosion, transport and deposition. They can also be derived from anthropogenic sources in which case they are incorporated into sediments as artificial pollutants from industrial or urban releases and wastes (Bermea *et al*., 2002). Their low I_{geo} index are usually safe, but increased in I_{geo} index of these elements in the environment can be significantly destructive to plants and animal life (Macfarlane & Burchett, 2000). As such soil is feasibly the most endangered component of our environment which is open to potential contamination by a variety of different pollutants arising from majorly human activities such as nuclear, industrial, agriculture, among others (Djingova & Kuleff, 2000; Bermea *et al*., 2002; Kalantari*et al*., 2006).

Baseline data on trace element levels and contamination parameter such as geo-accumulation index in soil is beneficial to all agrarian communities particularly in fertilizer applications and identifying suitable agricultural activities on soil as well as in resource identification, management and land use planning (Wilcke, *et al*., 1998). Hence, there is the crucial need to ensure that adequate information on the trace element levels and contamination parameter of soil is available to the agrarian communities so as to identify which part of the soil is best for planting certain crops and also identify the type of fertilizer suitable for a particular soil (Emanuel, 2015).

Despite the importance of baseline data on trace elements and geo-accumulation index to agrarian communities none of such study was conducted in Fika local government area of Yobe state. Most researches on the trace elements concentration in Nigeria were conducted on water system (Asubiojo *et al*., 1997; Mombeshora *et al*., 1983; Ndiokwere &

Cumie, 1983; Nriagu, 1986; Nriagu & Pacyna, 1988) with few studies on soil samples (Akanle *et al.*, 1994; Ogunsola *et al.*, 1994; Onianwa, 2001; Oyedele *et al.*, 1995 Abubakar, 2007; Emanuel, 2015). It is against this background that this study intends to determine the concentration levels and geo-accumulation indices of trace element using MP-AES analytical.

The assessment of soil contamination can be carried out in many ways. The most common ones are the index of geo-accumulation and enrichment factors (Lu *et al.*, 2009). In this work, the index of geo-accumulation (I_{geo}) has been applied to assess trace elements (Al, Cd, Cr, Co, Fe, Mn, Pb & Zn) distribution and contamination in Fika local government area of Yobe, Nigeria. A quantitative measure of the extent of trace element pollution in the studied soil was calculated using the geo-accumulation index proposed by Muller (1969)

The MP-AES is an important technique for the multi-element analysis of a wide range of materials which uses the fact that once an atom of a specific element is excited (as in atomic absorption), it emits light in a characteristic pattern of wavelengths – an emission spectrum, as it returns to the ground state. The wavelength of the atomic spectral line gives the identity of the element while the intensity of the emitted light is proportional to the number of atoms of the element. The relationship between the energy and wavelength is described by the Planck equation (Twyman, 2005):

$$E_j - E_i = hv = \frac{hc}{\lambda} \qquad (1.0)$$

where $E_j - E_i$ is the energy difference between the two levels (and $E_j > E_i$); h is Planck's constant, 6.624×10^{-34} Js^{-1}; v is the frequency of the radiation; c is the velocity of light in vacuum, (2.9979×10^{8} ms^{-1}) and λ is the wavelength of the radiation in meters.

1.1 Study area

The study area comprised the whole of Fika local government area of Yobe State, Nigeria. Fika is located between latitude 11°17'16" North and longitude 11°18'28" East (Maplandia, 2017). It has an area of 2208 km² consisting of ten wards. It has a total population of 136,895 at the 2006 census with over 70% of the population involved in agricultural activities. The vegetation of Fika falls under Sudan savannah whose annual rainfall range from 500 mm to 1000 mm. Fika populace experience cool dry (harmattan) season from December to February with a minimum temperature of 22°C; a hot dry season from March to May with a maximum temperature range of 39°C to 42°C; a warm wet season from June to September with average temperature of 40°C and a less marked season after rainfall during the months of October to November with temperature of 28°C (Meteorological Station Potiskum, 2017).

2. Materials and Methods

2.1. Materials

The items used for data collection are as follows: Beaker (500ml), Stirrer, auger, Distilled water, Plastic container (200 ml), Digestion tubes, Hot plate (adjustable), Reagents (HCl and HNO_3), Plastic bottles (50 ml), Marker and masking tape, Ruler, Weighing balance (M. AE240), Plastic mesh sieve, Agilent 4200 MP-AES, GPS device and Hand gloves.

The instrument used for sample measurement and analysis is *Agilent 4200 MP-AES* located in the Multi-user Science Laboratory of Ahmadu Bello University Zaria. The samples locations were sited using Global Positioning System (GPS) device and coded as in Table 1 and Figure 1 below.

Sample Code	Sample Ward	Sample Coordinates Latitude	Longitude	Collection Area/Village	Elevation (m)
FKA_1	Fika/Anze	Lat. 11°14'40.9"N,	Long. 011°19'37.1"E	Anze	325
FKA_2	Janga/Boza	Lat. 11°34'40.2"N	Long. 011°12'18.3"E	Dogo Abare	463
FKA_3	Ngalda/Dumbulwa	Lat. 11°06'15.8"N,	Long. 011°22'02.3"E	Ngalda	260
FKA_4	Turmi/Maluri	Lat. 11°18'19.1"N,	Long. 011°22'26.4"E	Turmi	363
FKA_5	Zangaya/Mazawun	Lat. 11°16'59.1"N,	Long. 011°22'16.4"E	Gashua	345
FKA_6	Gadaka/Shembire	Lat. 11°16'54.0"N,	Long. 011°10'09.0"E	Ngeji	335
FKA_7	Daya/Chana	Lat. 11°32'36.1"N,	Long. 011°02'26.8"E	Daya	449
FKA_8	Mubi/fusami	Lat. 11°15'06.9"N,	Long. 011°17'37.0"E	Badawa	340
FKA_9	Gudi/Dozi	Lat. 11°19'19.3"N,	Long. 011°03'05.6"E	Gamari	438
FKA_{10}	Shoye/Garin Aba	Lat. 11°16'12.3"N,	Long. 011°06'40.4"E	Garin Ada	405

Table 1: Sampling Points and Location of Soil Sample

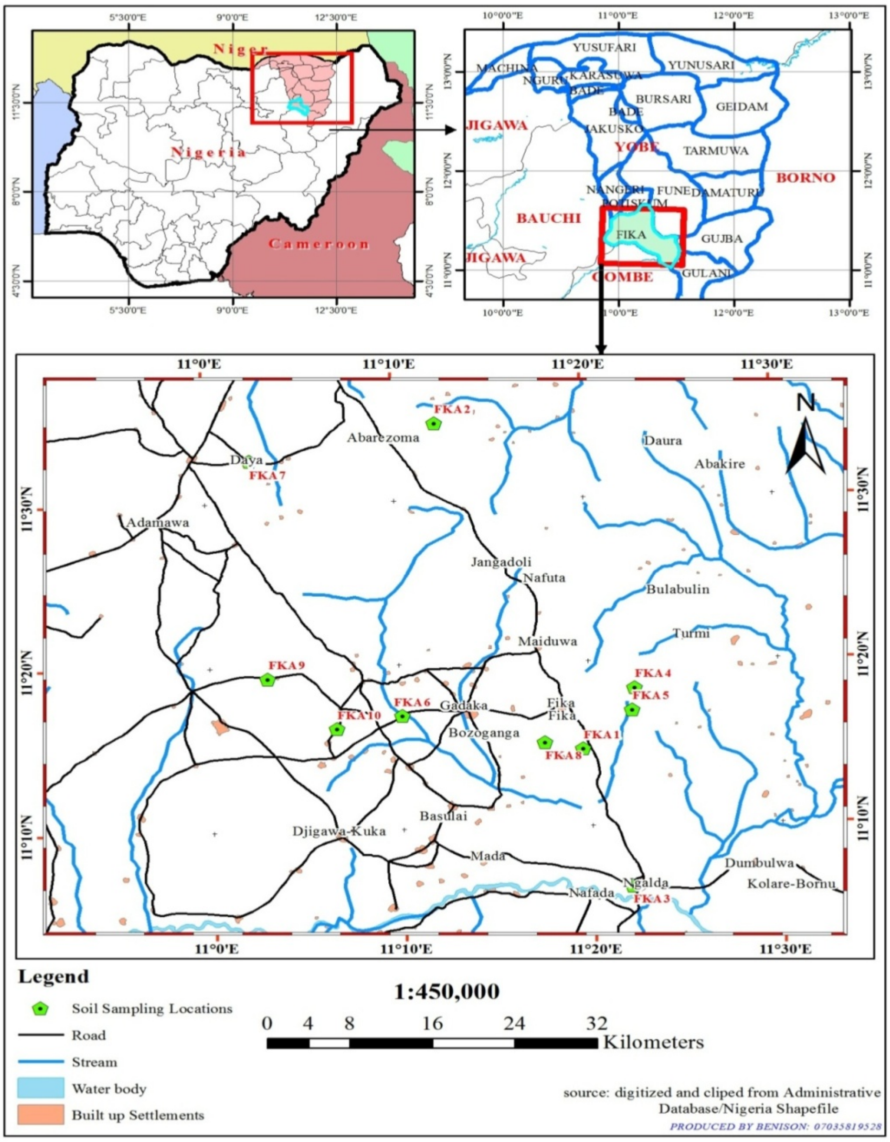

Figure 1: Map of Fika Local Government Yobe State Showing Sample Locations

2.2. Sample Collection, Preparation and Experimental Procedure

Representative soil samples from ten (10) wards were collected from farmland of the study area and GPS device was used to mark the coordinates and elevation above sea level. Three soil samples were collected at a depth of 0 to 20cm using soil auger from each ward. The samples were carefully mixed and put into clean and labelled plastic containers for analyses in the laboratory. Nitic acid ($HN0_3$) and Hydrochloric acid (HCl) were mixed together in the ratio of 3:1 in order to form the wet digestion acid mixture. 0.5g of each of the samples was transferred into digestion tubes, 30ml of the wet digestion acid mixture were added to each. The solutions were heated on hot plate at about 100^{o}C until clear solutions were obtained. Then the digestion process was discontinued and the digest were allowed to cool and transferred into volumetric flasks, they were made up to the mark of 50ml with distilled water. The digest of each sample was transferred into the different 50ml plastic bottles which were made ready for MP-AES analysis. Standard procedure was followed to determine the EC of the samples using Agilent 4200 MP-AES machine.

2.3. Quality Control

The validation of MP-AES was achieved by using standard reference materials (SRMs) of similar matrix as a control for the sample under investigation. The accuracy of the entire system could be established by observing the variation in the precision between differences with the literature value and the experimental values. Three UL and ISO certified standard reference materials were used: MP-AES wavecal (part number: 6610030100 & Lot number: 0000754061), ICP-MS7500CS (part number: 5185-5959 & lot number: 19-39GSX2) and ICP-OES wavecal (part number: 6610030000) were used as SRMs for the validation of the analytical result. The standards were manufactured under UL and ISO 9001 quality Assurance System.

2.4. Data analysis: The parameters of interest to be determined and their associated variables are given below:

2.4.1. Elemental Concentration (EC)

The EC gives the concentration in ppm of each trace element in the study area for the ten composite samples collected. The *EC* can be calculated using the following relations (Abolude, *et al*., 2009)

$$EC = \frac{Instrumentreading(ppm) - Blank(ppm)xfinalvolumeprepared(l)}{Weightofthesample(g)} \quad (2.0)$$

In this study, the final sample volume prepared after digestion is 50ml, blank = 0.000 and 0.5g weight of the prepared samples were used.

2.4.2. Geo-Accumulation Index (I_{geo})

Geo-accumulation index (I_{geo}) values permit the assessment of degree of soil contamination with respect to global standards. I_{geo} is calculated from the following equation (3.0):

$$I_{geo} = \log_2 \left(\frac{Cn}{Bnx1.5}\right) \quad (3.0)$$

where, C_n is measured total concentration of the examined element '*n*' in the studied soil, B_n is average shale geochemical surrounding value for concentration of the trace elements and 1.5 is the factor compensate for the surrounding data (correction factor) due to lithogenic effect (Golekar, *et al*, 2013). The geochemical background concentrations values of trace elements in soil are the average concentration of the elements in the shale (Turekian and Wedepohl, 1961) and displayed in Table 4.3.

The I_{geo} values according to Golekar, *et al*., (2013) are classified according to level of contamination as follows: Uncontaminated ($I_{geo} \leq 0$); Uncontaminated to moderately contaminated ($0 < Igeo \leq 1$); Moderately contaminated ($1 < I_{geo} \leq 2$); Moderately to heavily contaminated ($2 < I_{geo} \leq 3$); Heavily contaminated ($3 < I_{geo} \leq 4$); Heavily to extremely contaminated ($4 < I_{geo} \leq 5$); Extremely contaminated ($I_{geo} \geq 5$).

The data obtained were analyzed using the SPSS statistical software version 20. Mean, range and standard deviation descriptive statistics as well as Pearson Product Moment Correlation (PPMC) inferential statistic were used to analyze the data.

3. Results and Discussion

The Microwave Plasma Atomic Emission Spectroscopy (MP-AES) analysis results of soil in the study area shows presence of Aluminium (Al), Cadmium (Cd), Cobalt (Co), Chromium (Cr), Iron (Fe) Manganese (Mn), Lead (Pb) and Zinc (Zn) for all the samples at 0 to 20cm soil depths. The average elemental concentrations of trace elements are depicted in table 2 which indicate that all Cd and Co elemental concentrations were below detection limit except in FKA_4 and FKA_9 respectively. While Zn concentrations in FKA_9 and FKA_{10} were below detection limit; and of all elemental concentration only Pb in FKA_1 was found to be above the International Benchmark Concentration.

	LOCATION CODES									
Element	**FKA_1**	**FKA_2**	**FKA_3**	**FKA_4**	**FKA_5**	**FKA_6**	**FKA_7**	**FKA_8**	**FKA_9**	**FKA_{10}**
Al	2.793	2.507	7.002	4.815	9.387	1.649	3.607	4.559	1.213	1.877
Cd	BDL	BDL	BDL	0.001	BDL	BDL	BDL	BDL	BDL	BDL
Co	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.002	BDL
Cr	0.008	0.021	0.019	0.053	0.019	0.006	0.008	0.007	0.003	0.007
Fe	4.220	4.868	4.460	15.198	11.858	2.087	3.069	4.989	0.201	2.957
Mn	0.186	0.048	0.260	0.958	0.493	0.047	0.037	0.095	0.083	0.104
Pb	80.990	0.341	0.085	0.042	0.031	0.020	0.034	0.017	0.010	0.012
Zn	0.500	0.020	0.022	0.067	0.024	0.008	0.014	0.056	BDL	BDL

Table2: Elemental Concentration (EC) Of Trace Element in Soil Samples Values in Ppm.
BDL – Below Detection Limit

Table 2 shows the geo-accumulation indices (I_{geo}) of each trace element in soil of the study area. All the geo-accumulation indices were negative except Fe in locationsFKA_2, FKA_3, FKA_4, FKA_5, FKA_8 as well as Pb in FKA_1 which are positive. However Geo-Accumulation Index (I_{geo}) cannot be computed for Cd in FKA_1, FKA_3, FKA_4, FKA_5 FKA_6, FKA_7, FKA_8, FKA_9, and FKA_{10} ; for Co in FKA_1, FKA_2, FKA_3, FKA_4, FKA_5, FKA_6, FKA_7, FKA_8, and FKA_{10}, as well as for Zn in FKA_9 and FKA_{10} because their elemental concentration were below detection limit.

Element	FKA_1	FKA_2	FKA_3	LOCATION CODES FKA_4	FKA_5	FKA_6	FKA_7	FKA_8	FKA_9	FKA_{10}
Al	-1.83	-1.99	-0.50	-1.04	-0.08	-2.59	-1.46	-1.12	-3.04	-2.40
Cd	-	-7.23	-	-	-	-	-	-	-	-
Co	-	-	-	-	-	-	-	-	-13.25	-
Cr	-13.48	-12.09	-12.23	-10.75	-12.23	-13.90	-13.48	-13.67	-14.90	-13.67
Fe	-0.06	0.14	0.12	1.79	1.43	-1.08	-0.52	0.18	-4.46	-0.58
Mn	-12.19	-14.15	-11.71	-9.83	-10.79	-14.18	-14.52	-13.16	-13.36	-13.03
Pb	1.05	-6.84	-8.84	-9.86	-10.30	-10.93	-10.16	-11.16	-11.93	-11.67
Zn	-7.79	-12.44	-12.30	-10.69	-12.18	-13.76	-12.95	-12.95	-	-

Table 3: Geo-accumulation Indices (Igeo) Of Element In Soil Samples Of The Study Area

Table 3 shows the statistical summary showing mean I_{geo} values and I_{geo} class of each trace element. All the mean I_{geo} values of trace elements obtained are ≤ 0 which implies that they all fall within I_{geo} class≤ 0. Hence all the soil samples analysed in the study area were Uncontaminated.

Elements	n	Mean	I_{geo} class	Remark
Al	10	-1.562	≤ 0	Uncontaminated
Cd	1	-7.230	≤ 0	Uncontaminated
Co	1	-13.250	≤ 0	Uncontaminated
Cr	10	-12.483	≤ 0	Uncontaminated
Fe	10	-0.304	≤ 0	Uncontaminated
Mn	10	-12.690	≤ 0	Uncontaminated
Pb	10	-9.063	≤ 0	Uncontaminated
Zn	8	-11.634	≤ 0	Uncontaminated

Table 4: Statistical Summary Showing Mean, I_{geo} Class of Trace Elements in Soil Samples from the Study Area

Table 4 shows the PPMC correlation coefficients of I_{geo} values of trace elements in the study area. Strong positive correlations were obtained between Fe – Al and Zn – Pb at significant level of 0.05 and moderate positive correlation was found between Mn – Al. However, correlation between Cd and Co with themselves and any other trace element cannot be computed since they only have one constant elemental concentration values. Moderate negative correlation was obtained between Cr – Zn, as well as moderate positive correlation was found between Cr – Fe and Mn – Zn amongst others.

Elements	Al	Cd	Co	Cr	Fe	Mn	Pb	Zn
Al	1.000							
Cd	CC	CC						
Co	CC	CC	CC					
Cr	0.178	CC	CC	1.000				
Fe	0.741*	CC	CC	0.366	1.000			
Mn	0.619	CC	CC	0.208	0.573	1.000		
Pb	0.049	CC	CC	-0.137	0.210	0.111	1.000	
Zn	0.030	CC	CC	-0.542	0.268	0.420	0.782*	1.000

Table 5: The PPMC coefficients of Geo-Accumulation Index (I_{geo}) of trace elements in the study area
**Correlation Is Significant At The 0.05 Level.*
Cc = Cannot Be Computed Because At Least One Of The Variables Is Constant

Based on the research result obtained, the mean elemental concentration is of the order of Pb (81.585 ± 25.591) > Fe (53.907 ± 4.593) > Al (3.941 ± 2.595) > Mn (2.311 ± 0.291) > Zn (0.500 ± 0.167) > Cr (0.151 ± 0.015) > Co (0.002 ± 0.000) > Cd (0.001 ± 0.00) in ppm respectively. In all the trace elements detected Pb in FKA_1 was found to be above the USDE International benchmark Concentration (Efroymson *et al.*, 1997) which might be because of the gypsum mining activities being carried out in the area. The finding of this study is supported by Buba and Aboyeji (2015) studies which found high concentration of Lead (Pb) in Zamfara mining sites. Since Fika is an agrarian community, the presence of plants' micro nutrients such as Fe, Zn and Mn below the USDE international benchmark is of agricultural advantage. All the I_{geo}, Index values computed were negative except Fe and Pb I_{geo} values in six samples locations in the study area. This is in line with the study by Golekar, et al (2013). However negative I_{geo} values were obtained for all the over elements which imply the study area was uncontaminated. Nevertheless, strong I_{geo} value correlations were obtained between (Zn – Pb) and (Al - Fe) at 0.5 alpha level.

4. Conclusion

Based on the MP-AES result of this study, the elemental concentration and geo-accumulation index of Al, Cd, Cr, Co, Fe, Mn, Pb and Zn were determined correlated and compared USDE international benchmark. The maximum and minimum elemental concentration ranges obtained are: Al (1.213 –7.002)ppm, Cd (BDL – 0.001)ppm, Co (BDL – 0.002)ppm, Cr (0.003 – 0.053)ppm, Fe (0.201 – 15.198)ppm, Mn (0.037 – 0.0958)ppm, Pb (0.010 – 80.990)ppm and Zn (0.008 – 0.500)ppm with the order of Pb (81.585) > Fe (53.907) > Al (3.941) > Mn (2.311) > Zn (0.500) > Cr (0.151) > Co (0.002) > Cd (0.001) in ppm respectively. The result further revealed that all the mean I_{geo} values of trace element were < 0 (uncontaminated). It can therefore be concluded that the study area soil samples are uncontaminated. Therefore, the study among others recommended that there is need to extend the scope of the study to cover radiological contaminants in soil, plants and river sediments in the study area so as to obtain a composite baseline data.

5. References

i. Abolude, D. S., Davies, O. A. & Chia, A. M. (2009). Distribution and concentration of traceelements in kubani reservoir in northern Nigeria. Research journal of environmental
ii. And earth sciences 1(2): 39-44.
iii. Abubakar, K. S. (2007). Physical properties and elemental abundances of the Nigerian Savannah soils. Published Msc thesis Ahmadu Bello University Zaria Nigeria. 13-18
iv. Addis, W.& Abebaw, A. (2018). Determination of heavy metals Concentration in soil used for cultivation of Allium Sativum L. (galic) in East Gojjam zone, Amhara Regio Ethiopia. Retrieved from https://www.tandfonline.com/doi/full/10.11080/2331200Agilent Technologies Incorp. ATI (2015). AES Applications. Primer, UK. 20 - 23.
v. Akanle, O. A. et al. (1994). Traffic pollution: Preliminary elemental characterization of road side dust in Lagos, Nigeria. Sci. Total Environ. 146(147): 175-184.
vi. Asubiojo O. I., Nkono N. A., Ogunsola A. O., Oluwole, A. F., Ward, N. I., Akanle O. A. & Spyrou N. M. (1997). Trace elements in drinking and ground water samples in Southern Nigeria. Sci. Total Environmental, 208: 1-8.
vii. Bermea, O. M., Alvarez, A. H., Gaso, I. & Segovia, N. (2002). Heavy metal concentration in surface soil from Mexico City. Bull. Environ. Contam. Toxicol., 68:383-388
viii. Buba, N. F & Aboyeji, S. O. (2015). Geospatial Analysis of concentration in the soil Anka,
ix. Zamfara State, Nigeria. Greener journal of environmental management and public safety, 4(3), 28 – 36.
x. Chaney R. L. & Oliver D. P. (1996). Sources, potential adverse effects and remediation of agricultural soil contaminants, in Contaminants and the Soil Environments in the Australia-Pacific Region, R. Naidu, Ed., pp. 323– 359.
xi. Djingova, R. & Kuleff I. (2000). Instrumental Techniques for Trace Analysis. In:Elements. Their Distribution and Effects in the Environment, Markert, B. and Friese, K. (Eds). Elsevier, Amsterdam, Pp: 137-185.
xii. Efroymson, R.A., Will, M. E., Suteer II, G. W. & Wooten, A. C. (1997). Technological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants. US Department Energy ES/ER/TM- 85/R3. P. 2-5
xiii. Emmanuel, S. A. (2014). Level of Heavy metals and their Bioavailability in soil in Kakuri industrial area of Kaduna. Unpublished M.SC. Analytical Chemistry Thesis, Faculty of Science, ABU Zaria.
xiv. Golekar R B, Baride M V, Patil S.N & Yeole D. R. (2013). Assessment and investigation of trace element in soils with reference to Geo-accumulation Index. International Journal of Environmental Sciences. 4(1), 54
xv. Khan S., Cao Q., Zheng Y. M., Huang Y. Z., and Zhu Y. G.(2008). Health Risks of Heavy Metals in Contaminated Soils and Food Crops Irrigated With Wastewater in Beijing, China, Environmental Pollution, 152(3): 686–692.
xvi. Kalantari, M. R., Shokrzadeh, M., Ebadi, A. G., Mohammad izadeh, C., Choudhary, M. I. and Rahman, A. (2006). Soil pollution by heavy metals and remediation (Mazandaran-Iran). J. Applied Sci., 6, 2110-2116
xvii. Lu, X., L. Wang, K. Lei, J. Huaing & Y. Zhai, 2009. Contamination assessment of copper, lead, zinc, manganese and nickel in street dust of Baoji, NW China. J. Hazard. Mater., 161: 1058-1062.
xviii. Muller, G., 1969. Index of geo-accumulation in sediments of Rhine river. J. Geol., 2: 108-118.
xix. Macfarlane, G. R. & Burchett, M. D. (2000) Cellular distribution of Cu, Pb and Zn in the grey mangrove Avicenniamarina (Frorsk) Vierh Aquatic Botany , 68, pp 45-59.
xx. Maplandia (2017). Fika Map; Satellite Images of Fika. Retrieved from: www.maplandia.com/nigeria/yobe/fika/fika.com.
xxi. Mathias, O. N & Stephen N. U, (2016) Use of Enrichment, Ecological Risk andContamination Factors with Geo-accumulation Indexes to Evaluate Heavy Metal Contents in theSoils around Ameka Mining Area, South of Abakaliki, Nigeria Journal of Geography, Environment and Earth Science International 5(4), 1-13
xxii. McLaughlin, M.J., Parker, D.R. & Clarke, J.M. (1999). Metals and micronutrients-food safety issues. FieldCrops Res., 60: 143-163 Metrological Station Potiskum. (2017).
xxiii. Mombeshora, C., Osibanjo, O & Ajayi, S. O. (1983). Pollution studies on Nigerian rivers: The onset of lead pollution ofsurface waters in Ibadan. Environ. Int., 9: 81-84.
xxiv. Ndiokwere, C. L. & Cumie, V. P., (1983). Determination of some toxic trace metals in Nigeria Rivers and harbour water samples by INAA. J. Radioanal. Nucl. Chem., 79: 147-151.
xxv. Nriagu, J. O., (1986). Chemistry of the river Niger, I: major ions, II: trace metals. Sci. Tot. Environmental, 58: 81-92.

xxvi. Nriagu, J. O. & Pacyna, J. M., (1988). Quantitative assessment of world-wide contamination of air, water and soils by trace metals. Nature, 333: 134-139.

xxvii. Ogunsola, O.J. Oluwole, A.F. & Asubiojo, O .I. Olaniyi, H.B. Akeredolu, F. A. Akanle, O. A. Spyrous, N. M. Ward, N. I. Ruck, W. (1994). Traffic pollution: Preliminary elemental characterization of road side dust in Lagos, Nigeria. Sci. Total Environ. 146 / 147:175-184.

xxviii. Onianwa, P. C. (2001). Roadside topsoil concentrations of Lead and other heavy metals in Ibadan, Nigeria. Soil Sediment Contam., 10: 577591.

xxix. Oyedele, D. J. Obioh, I.B. Adejumo, J. A. Oluwole, A. F. Aina, P. O. & Asubiojo, O. I. (1995).Lead contamination of soils and vegetation in the premises of a smelting factory in Nigeria. Science Total Environment. 172: 189-195.

xxx. Rahman, S. H., Khanam, D., Adyel, T. M., Mohammad, S. I., Ahsan, M. A. & Akbor, M. A. (2012). Assessment of Heavy Metal Contamination of Agricultural Soil around Dhaka

xxxi. Export Processing Zone (DEPZ), Bangladesh: Implication of Seasonal Variation and Indices. Applied Science Journal 2, 584-601.

xxxii. Sanda, Y. S. (2015). Assessment of Heavy Metal contamination in Irish Potatoes and Soils from an abandoned Mining site in jos-south, using AAS and XRF techniques. Unpublished M.sc. thesis in Radiation Biophysics, Ahmadu Bello University Zaria.

xxxiii. Shekeri, A., Afrasiabian, A., Rezaei, M. & Karimi, M. (2014). Assessment of Trace Elements Contamination in Surface Sediment of Bakhtegan Lake, Iran. Iranian Journal of Science and Technology, 38(1) 75-85.

xxxiv. Turekian K. K. and Wedepohl, K. H. (1961). Distribution of the elements in some major unit of the earth's crust. Bulletin of Geological Society of America. 72: 175–92.

xxxv. Twyman, R. M. (2005). Atomic Emission Spectrometry.University of York, UK Elsevier, p. 190-198.

xxxvi. Wilcke, W., Kretzschmar, S., Bundt, M. Saborío, G. & Zech, W. (1998). Aluminum and heavy metal partitioning in A horizons of soils in Costa Rican coffee plantations. Soil Science 163, 463-471.

xxxvii. Yousef A A, Maie, I. E., Mahmoud, S. I. & Mohammed A. O, (2017). Distribution and Assessment of Heavy Metal Levels Using Geo-accumulation Index and Pollution Load Index in Lake Edku Sediments, Egypt. InternationalJournal of Environmental Monitoring and Analysis. Vol. 5, No. 1, 2017, pp. 1-8.