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Investigation Of Contaminated Level In Soil From Fika Agrarian Communities Of Yobe State, Nigeria, Using MP-AES Analytical Technique

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ABSTRACT

This study examined the concentration level, contamination factor (CF) and pollution load index (PLI) of trace element in soil samples from agrarian communities 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), contamination factor (CF) and pollution load index (PLI) 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) > Fe (53.907) > Al (3.941) > Mn (2.311) > Zn (0.500) > Cr (0.151) > Co (0.002) > Cd (0.001) in ppm respectively, of all the trace elements detected, only Pb in FKA_1 was found to be above the International benchmark. Moreover, The result further revealed that all the mean values of contamination factor for trace element were all < 1 except Fe whose CF class fall within1 $\leq$ CF < 3 class which implies that they all have low contamination factors except Fe whose contamination factor was moderate. The PLI values fall within <1 PLI class which implies that all the sample locations were unpolluted. Correlation analysis showed a strong correlation coefficient between Zn and Pb for CF values. It was recommended that the farmers can cultivate their cereals crops as the soil has a moderate elemental concentration for the purpose and may apply macro element fertilizer to argument and sterile the soil with high concentration like nitrogen, phosphorus, potassium among others.

***Keywords**:* Trace element, Fika, pollution load index, Microwave-Plasma Atomic Emission Spectroscopy, Soil contamination.

1.0 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 contamination level is usually safe, but increased in contamination level 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 contamination levels in soil is beneficial to all agrarian communities particularly for 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 concentration levels of trace element 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).

To the best of my knowledge despite the importance of baseline data on trace elements, contamination factor and pollution load 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, contamination factor and pollution load 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, contamination factor, pollution load index (PLI) and enrichment factors (Lu *et al*., 2009). In this work, elemental concentration, contamination factor (CF) and pollution load index (PLI) has been applied to assess trace elements (Al, Cd, Cr, Co, Fe, Mn, Pb & Zn) contamination in Fika local government area of Yobe State, Nigeria. A quantitative measure of the extent of trace element pollution in the studied soil was calculated using the mathematical expression of contamination factor and pollution load indices proposed by (Odat, 2015) & (Anthony, *et al*, 2014) respectively.

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):

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

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}; ν 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.

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)

$$EC = \frac{\text{Instrument reading (ppm) – Blank (ppm) x final volume prepared (l)}}{\textit{Weight of the sample (g)}} \qquad (2.0)$$

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

Contamination Factor (CF)

The contamination factor (CF) is a pointing factor to the contamination level of heavy metals in the soil samples. The contamination factor can be calculated through the following formula as suggested by (Harikumar *et al.,* 2009; Odat, 2015).

$$CF = \left(\frac{C_x}{C_r}\right)_{sample} \qquad (3.0)$$

Where C_x is the mean concentration of elements from sampling sites in the study area and *Cr* is the concentration of the examined element in the reference environment. The CF values are classified as:

Table 1.0: Classification of Contamination Factor.

S/N	Values	Classification
1	CF < 1	Low contamination factor
2	$1 \leq CF < 3$	Moderate contamination factor
3	$3 \leq CF < 6$	Considerable contamination factor
4	$6 \leq CF$	Very high contamination factor

(Source: Rahman, *et al*, 2012).

Pollution Load Index (PLI)

An effective parameter to determine the magnitude of trace elements contamination in the soil samples is the Pollution Load Index (PLI). The PLI for each sample location was evaluated using equation 3.4 below.

$$PLI_k = (CF_1 \times CF_2 \times CF_3 \times ....CF_n)^{1/n} \quad (4.0)$$

Where: k= sample locations, n = number of metals and CF = contamination factor. A PLI value > 1 is polluted sample while PLI value < 1 indicates no pollution (Anthony, *et al*, 2014). For this study, equation 4.0 can be rewritten as

$$PLI_k = (CF_{Al} \times CF_{Cd} \times CF_{Co} \times CF_{Cr} \times CF_{Fe} \times CF_{Mn} \times CF_{Pb} \times CF_{Zn})^{1/8} \quad (5.0)$$

Where: k= sample locations FKA_1, FKA_2, FKA_3, FKA_4, FKA_5, FKA_6, FKA_7, FKA_8 FKA_9 and FKA_{10} while n = number of elements under study equal to eight (8).

MATERIALS AND METHOD

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, 2023). It has an area of 2208 km^2 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 22^0C; a hot dry season from March to May with a maximum temperature range of 39^0C to 42^0C; a warm wet season from June to September with average temperature of 40^0C and a less marked season after rainfall during the months of October to November with temperature of 28^0C (Meteorological Station Potiskum, 2023).

Materials and Equipment used:

The materials/ equipment used for MP-AES analysis include the following:

i. Beaker (500ml)
ii. Soil auger
iii. Plastic container (200 ml)
iv. Hot plate (adjustable)
v. Plastic bottles (50 ml)
vi. Ruler
vii. Plastic mesh sieve
viii. GPS device.
ix. Stirrer
x. Distilled water
xi. Digestion tubes
xii Reagents (HCL & HNO_3)
xiii. Marker and masking tape
xiv. Weighing balance(M. AE240)
xv. Agilent 4200 MP-AES.
xvi. Hand gloves

Agilent 4200 MP-AES was used for the AES analysis in the Multi-user Science Laboratory of Ahmadu Bello University Zaria.

Sample locations:

The study was carried out in ten (10) sample locations within the Fika agrarian community. The locations were sited using Global Positioning System (GPS) device and coded as in Table 1 and figure 1.

Table 1: Sampling points and location of soil sample

Sample Code	Sample Coordinates by GPS Latitude	Longitude	Agrarian Communities	Elevation in metre
FKA_1	Lat. $11^0$14'40.9"N,	Long. $011^0$19'37.1"E	Anze	325
FKA_2	Lat. $11^0$34'40.2"N,	Long. $011^0$12'18.3"E	Dogo Abare	463
FKA_3	Lat. $11^0$06'15.8" N,	Long. $011^0$22'02.3"E	Ngalda	260
FKA_4	Lat. $11^0$18'19.1"N,	Long. $011^0$22'26.4"E	Turmi	363
FKA_5	Lat. $11^0$16'59.1"N,	Long. $011^0$22'16.4"E	Gashua	345
FKA_6	Lat. $11^0$16'54.0"N,	Long. $011^0$10'09.0"E	Ngeji	335
FKA_7	Lat. $11^0$32'36.1"N,	Long. $011^0$02'26.8"E	Daya	449
FKA_8	Lat. $11^0$15'06.9"N,	Long. $011^0$17'37.0"E	Badawa	340
FKA_9	Lat. $11^0$19'19.3"N,	Long. $011^0$03'05.6"E	Gamari	438
FKA_{10}	Lat. $11^0$16'12.3"N,	Long. $011^0$06'40.4"E	Garin Ada	405

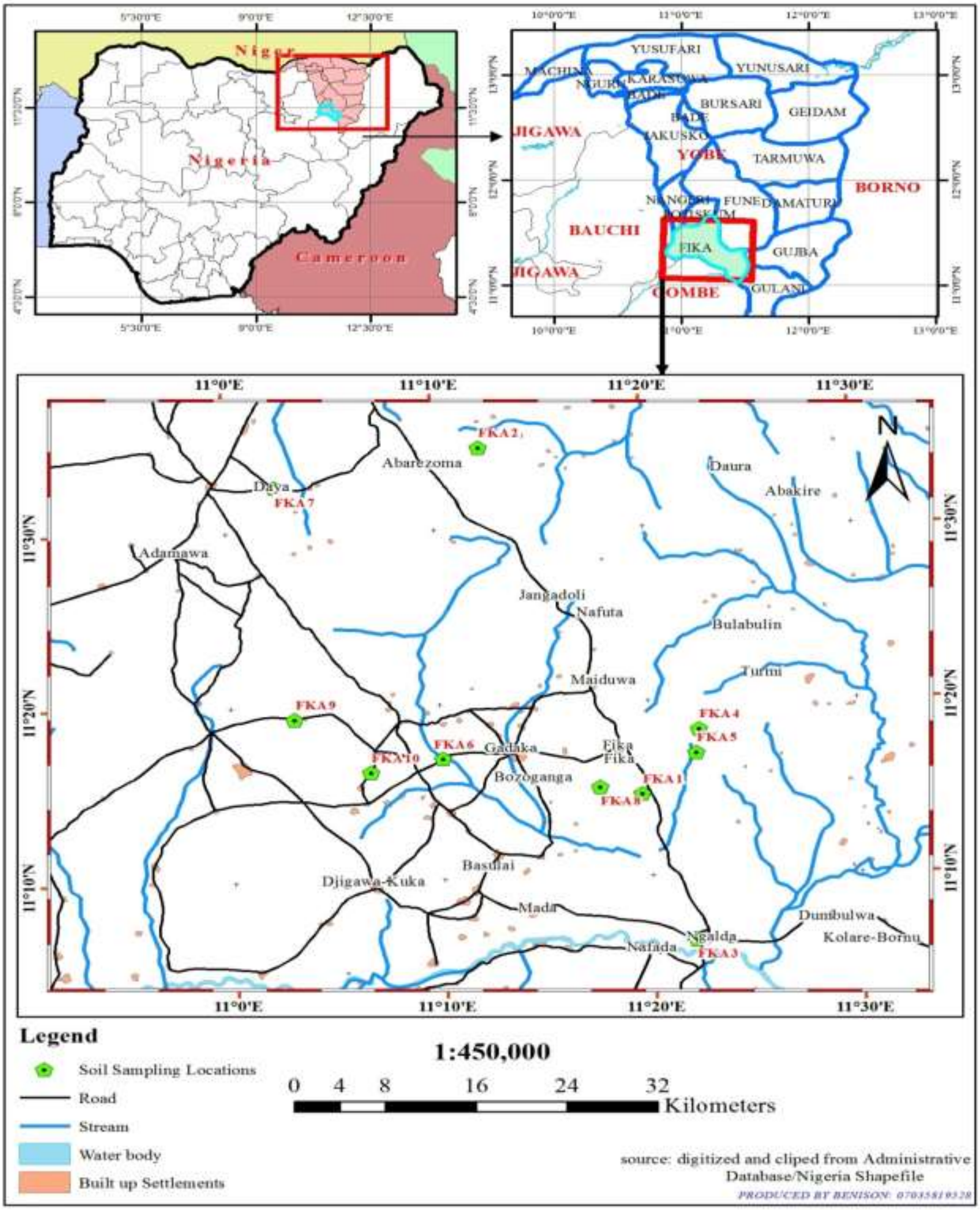

Fig. 1: Map of Fika Local Government Yobe State Showing Sample Locations

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. $HN0_3$ and 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°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 determine the EC of the samples using Agilent 4200 MP-AES machine.

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.

Statistical analysis: 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.

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. This might be due to the gypsum mining activity being carried out in the study area. The finding is supported by Buba and Aboyeji (2015) studies which found high concentration of Lead (Pb) in Zamfara mining sites.

Table 3: Elemental Concentration (EC) of trace element in soil samples values in ppm.

	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	1.69	3.67	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	0.06	0.08	0.007	0.003	0.007
Fe	4.220	4.868	4.460	15.198	11.858	2.07	3.09	4.989	0.201	2.957
Mn	0.186	0.048	0.260	0.958	0.493	0.07	0.07	0.095	0.083	0.104
Pb	80.990	0.341	0.085	0.042	0.031	0.00	0.04	0.017	0.010	0.012
Zn	0.500	0.020	0.022	0.067	0.024	0.08	0.04	0.056	BDL	BDL

BDL – Below Detection Limit

Table 4 below shows the Contamination factor (CF) of each trace element in soil of the study area. CF cannot be computed for Cd in FKA_1, FKA_2, FKA_3, 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. However, the values for Cr and Mn are negligible and tending to zero in all the sample locations. The highest CF obtained was 5.169 of Fe in FKA_4.

Table 4: Contamination Factor of Trace Element in Soil Samples of the Study Area.

	LOCATION CODES									
Element	FKA_1	FKA_2	FKA_3	FKA_4	FKA_5	FKA_6	FKA_7	FKA_8	FKA_9	FKA_{10}
Al	0.422	0.379	1.058	0.727	1.418	0.249	0.545	0.689	0.183	0.284
Cd	-	-	-	0.010	-	-	-	-	-	-
Co	-	-	-	-	-	-	-	-	0.000	-
Cr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe	1.435	1.656	1.517	5.169	4.033	0.710	1.044	1.697	0.068	1.006
Mn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pb	3.155	0.013	0.003	0.002	0.001	0.000	0.001	0.000	0.000	0.000
Zn	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-	-

Table 5 shows the Statistical summary showing mean CF values and CF class of each trace element. All the mean CF values of trace elements were < 1 except Fe whose CF class fall within1 ≤ CF < 3 class which implies that they all have low contamination factors except Fe whose contamination factor was moderate. This is in support of study by Emmanuel (2014) which contains all low contamination factors.

Table 5: Statistical summary showing Mean, CF Class and Remark of Contamination factor (CF) of trace element in soil samples of the Study Area.

Elements	n	Mean	CF class	Remark
Al	10	0.595	< 1	LCF
Cd	1	0.010	< 1	LCF
Co	10	0.000	< 1	LCF
Cr	1	0.000	< 1	LCF
Fe	10	1.834	1 ≤ CF < 3	MCF
Mn	10	0.000	< 1	LCF
Pb	10	0.318	< 1	LCF
Zn	8	0.001	< 1	LCF

Table 6 shows the PPMC correlation coefficients of contamination factor of trace elements in the study area. All the correlation coefficients cannot be computed since they only have one constant elemental concentration values except Fe - Al (0.655^{*}: strong +ve correlation), Zn - Pb (1.000^{**}: perfect +ve corretion) and negetively weak correlations between Pb - Al, Zn - Pb and Pb - Fe respectively.

Table 6: The PPMC correlation coefficients of Contamination Factor of trace of elements in the study area.

Elements	Al	Cd	Co	Cr	Fe	Mn	Pb	Zn
Al	1.000							
Cd	CC	CC						
Co	CC	CC	CC					
Cr	CC	CC	CC	1.000				
Fe	0.655*	CC	CC	CC	1.000			
Mn	CC	CC	CC	CC	CC	1.000		
Pb	-0.156	CC	CC	CC	-0.089	CC	1.000	
Zn	-0.275	CC	CC	CC	CC	CC	1.000**	1.000

*Correlation is significant at the 0.05 level. CC = cannot be computed because at least one of the variables is constant.

Table 7 shows the PLI of trace elements in the study sample locations. The Pollution Load Index values fall within <1 PLI class which implies that all the sample locations were unpolluted.

Table 7: Pollution Load Index (PLI) of Trace Element in Soil Samples of the Study Area.

Location	PLI	PLI class	Remark
FKA_1	$9.368X10^{-11}$	< 1	No Pullution
FKA_2	$5.981X10^{-15}$	< 1	No Pullution
FKA_3	$3.332X10^{-14}$	< 1	No Pullution
FKA_4	$5.067X10^{-15}$	< 1	No Pullution
FKA_5	$8.184X10^{-14}$	< 1	No Pullution
FKA_6	$1.952X10^{-17}$	< 1	No Pullution
FKA_7	$1.500X10^{-16}$	< 1	No Pullution
FKA_8	$1.812X10^{-15}$	< 1	No Pullution
FKA_9	$8.634X10^{-19}$	< 1	No Pullution
FKA_{10}	$5.719X10^{-13}$	< 1	No Pullution

CONCLUSION

Based on the MP-AES result of this study, the elemental concentration, Pollution Load Index and contamination factor 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 contamination factor of trace element in the study area has values < 1 except Fe whose CF class fall within1 ≤ CF < 3 class which implies that they all have low contamination factors except Fe whose contamination factor was moderate. The PLI values fall within <1 PLI class which implies that all the sample locations were unpolluted. The researcher concludes that the study area is an uncontaminated and unpolluted. Since Fika is an agrarian community, the presence of plants micro nutrients such as Fe, Zn and Mn below the USDE benchmark is of agricultural advantage, Therefore, the study among others recommended that the farmers can cultivate their cereals crops as the soil has a moderate elemental concentration for the purpose and may apply macro element fertilizer to argument and sterile the soil with high concentration like nitrogen, phosphorus, potassium among others and there is need to extend the scope of the study to cover radiological contaminants in soil from cultivated farmlands, plants and river sediments in the study area so as to obtain a composite baseline data.

CONFLICT OF INTEREST

The authors declared no conflict of interest.

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