International Scholarly Research Network
ISRN Analytical Chemistry
Volume 2012, Article ID 594598, 8 pages
doi:10.5402/2012/594598

Research Article

Elemental Studies of Soil and Food Flour for Risk Assessment of Highway Pollution Using Particle-Induced X-Ray Emission (PIXE) Spectrometry

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Received 29 December 2011; Accepted 18 January 2012

Academic Editors: A. G. Asuero and R. K. Jyothi

The study investigated potential toxic elements in soils and food flours for highway pollution using PIXE spectrometry. The contaminated soils and cassava food flours contained higher levels of the elements than their control samples, while comparison with their standard permissible limits followed similar trend which was attributable to anthropogenic influences. These were corroborated by their elevated Enrichment factor, Pollution index and Geoaccumulation index values for the elements, suggesting *significant* anthropogenically—derived contaminations of the soils. *T*-test value (0.038) for the elemental composition of the contaminated soils & cassava flours was *significant* due to considerable higher concentrations of the elements in the soils than the cassava flours. Cross plot analysis result for the contaminated soils and cassava fours showed *moderate* positive correlation ($R^2 = 0.426$), indicating inter-element relationship between them. Cluster analysis results for the analyzed elements in the contaminated soil samples indicated that Mn, Fe, V, Cr, Zn, Cl, Ti and S showed closest inter-element clustering and was corroborated by the results of Pearson correlation matrices, while inter-element clustering in the food flour followed the same trend and was also supported by their results of Pearson correlation matrices, validating that the soils and cassava flours were contaminated via similar sources.

1. Introduction

Contamination of soil and subsequent food contamination by toxic elements is a major environmental problem that the scientific public is encountering nowadays. The contamination arises via both natural and anthropogenic activities. They are usually established in the soils by forming complexes with organic moieties thereby making their removal very tedious and they persist in the soil until taken up by plants and become part of food chain. Due to the fact that some of the elements, namely, heavy metals are nonbiodegradable, their contamination is difficult to take care of [1].

The occurrence of potential toxic elements above the natural concentrations in highway soils and urban soils is a universal phenomenon [2–8].

In Nigeria, similar studies have been conducted; for instance, in the study carried out by Olajire et al. [9], their report showed the presence of some heavy metals in some soils in an industrial city of southern Nigeria at elevated levels. Study on the contamination of roadside soil and Grass with heavy metals conducted by Olajire and Ayodele [10] revealed that the environmental matrices were contaminated with some heavy metals. Also, a survey of heavy metal deposition in Nigeria using the moss monitoring method conducted by Olajire [11] showed that the plants accumulated heavy metals from motor traffic.

High concentrations of potential toxic elements in metropolitan soils may imply a major input of anthropogenic contamination from numerous sources. These include air pollutants from vehicular emissions; combustion activities in industrial, commercial, and domestic areas; emissions from petroleum products retail stations; emissions from wood combustion [12]. It was reported that two most important sources of environmental contamination along British motorways were motor vehicles, and neighboring industrial and commercial activities. Motor vehicles provide the foremost contribution of metals from the combustion of fuel and by the corrosion, and wear and tear of vehicle parts such as brake linings, tyres [13].

Some elements are essential to life because they play major roles in blood building, bone formation, and functioning of critical enzyme system, for example, Fe, Cu, Ca, and Zn, while some (Hg, Cd, and As) are xenobiotic (i.e., they are neither essential nor beneficial in human physiology) but have negative effect to living organism's physiologies including man even, at low levels. Almost all elements that are essential are, however, injurious at elevated amounts [14]. Practically, all toxic elements have impacts on multiple organ systems with biochemical processes and/or organelles as targets. The toxicity of metals frequently harms brain and kidney; they are capable of causing other diseases such as cancer, anemia, hypertension, general weakness of the body, and headache [14, 15].

It is commonplace among the rural dwellers in Nigeria to sun dry food stuffs such as cassava, plantain and yam flours, and pepper along highways without the knowledge of toxic element contamination of these food stuffs via vehicular emissions, which can result in ill health of the innocent people that purchase these food stuffs for consumption. The intent of this study was to investigate the occurrence and concentrations of potential toxic elements—S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Zn, and Zr in the soil and food flour along highways using PIXE spectrometry analytical technique. The data obtained on the elements were interpreted using variation diagrams and other statistical techniques such as cross plot analysis, geoaccumulation index (I_{geo}), enrichment factors (EFs), pollution index (PI), and correlation matrix to establish relationship between the analyzed elements within the soil or food flour, and also interelemental relationship between the contaminated soil and food flour. This will indicate that contamination of the soil and food flour could have originated through similar sources.

PIXE analytical technique was employed in this study because it possesses a number of advantages over some of the other elemental analytical techniques, namely, its multi-elemental determination and nondestructive capabilities; small sample size requirement; very low detection limits up to part per billion (ppb) levels.

(a)

(b)

Figure 1: Pictures showing some of the sample locations.

2. Experimental

2.1. Sample Collection and Treatment. Dried cassava food flours were collected into polythene bags from 7 sites along Ile Ife-Ibadan highway, Nigeria (Figures 1(a) and 1(b)), while fresh 7 cassava samples (control samples) were also obtained and oven dried. Also surface soil samples (soil dusts) were collected very close to the food flour sampling sites, while soil samples (control samples) were obtained from areas of little or no anthropogenic activities, about 100 m away from highways. The composite and representative soil samples were prepared by air drying at room temperature in the laboratory but well covered with white sheets of paper to prevent air particulate contamination. These were then crushed and filtered to 2 mm mesh size, homogenized by coning and quartering. The cassava flour and soil samples were then pulverized to pass a 71 μ sieve using agate mortar. The powdered soils and cassava flours were put in polyethylene containers (7 mm × 10 mm) and sealed to avoid contamination and loss of material and then taken to the laboratory for analysis [16, 17].

2.2. Elemental Analysis. Each sample was mixed with 20% ultra-fine carbon in the mixer and pressed into pellet of 13 mm diameter. The rationale behind the addition of carbon was to reduce charging effects in the sample [18]. The PIXE elemental analysis was performed using a 3.0 MeV proton beam obtained from the ion beam analysis (IBA) facility of the 3 MV Van de Graff accelerator at Centre for Energy Research and Development, Obafemi Awolowo University, Ile-Ife, Nigeria. The facility is centered on an NEC 5SDH 1.7 MV Pelletron Accelerator, equipped with a radio frequency charge exchange ion source. The ion source is equipped to provide proton and helium ions. The end station consists of an aluminum chamber of about 150 cm diameter and 180 cm height. It has four pots and a window. Port 1 at 165° is for Rutherford Backscattering (RBS) detector, port 2 at 135° is for PIXE detector, port 3 is for ERDA detector, the window at 0° is for observing the beam position and the size, while port 4 at 225° is for PIGE. The chamber has a sample ladder that can carry eleven 13 mm diameter samples. The end station has a turbo pump and a variable beam collimator to regulate beam size and an isolation value. The measurements were carried out with a beam spot of 4 mm in diameter and a low beam current of 3–6 nA. The irradiation was for 10–20 minutes. A Canberra Si(Li) detector Model ESLX 30–150, beryllium thickness of 25 μm, with full width half

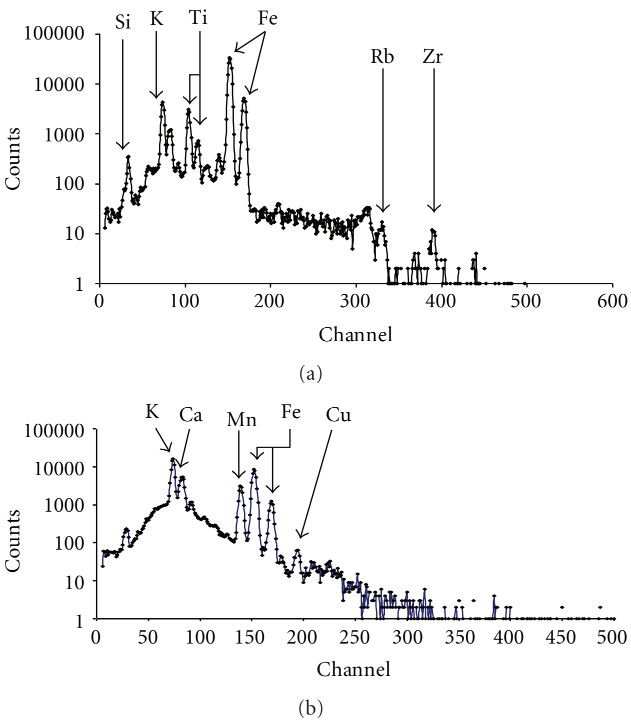

Figure 2: (a) PIXE spectrum obtained for a soil sample. (b) PIXE spectrum obtained for a cassava flour sample.

maximum of 150 eV at 5.9 keV, with the associated pulse processing electronics, and a Canberra Genie 2000 (3.1) MCA card interfaced to a PC were used for X-rays data acquisition. With respect to the sample beam director, the sample's was positioned at 0° and Si (Li) detector was positioned at 45° to the left of the beam. The PIXE spectrum for a soil sample and a cassava flour sample are presented in Figures 2(a) and 2(b), respectively. The PIXE spectrum was performed using GUPIXWIN software. This provided a nonlinear least square fitting of the spectrum, together with subsequent conversion of the fitted X-ray peak intensities into elemental concentrations, utilizing the fundamental parameter method for quantitative analysis.

2.3. Quality Assurance and Quality Control. International Atomic Energy Agency, IAEA reference material—IAEA-soil-7 and NIES reference material—RF10C (Rice flour) were prepared and analyzed for trace elements following the same protocols as the soil and cassava flour samples, respectively, and the results compared with the certified/recommended values. All analytical instruments used were calibrated and triplicate analyses were made.

3. Data Analysis

The overall data obtained for the two sets of samples were interpreted using appropriate descriptive and inferential statistical techniques such as charts, t-test, enrichment factor (EF), pollution index (PI), geoaccumulation index (I_{geo}), Pearson correlation matrix, cross-plot, and cluster analyses.

The EF is the quotient of the ratio of the concentration of element x to the concentration of reference element f in the sample to the same ratio in the crust [19]. EF is expressed as $(C_x/C_f)_{\text{sample}}/(C_x/C_f)_{\text{crust;}}$ where C_x and C_f are the concentrations of the element x and reference element f in the soil and reference samples [19–21].

The PI is the quotient of the concentration of the element x in the sample to the maximum permissible level of the element. $\text{PI}_{(x)}$ = concentration in the sample/maximum permissible level.

It is agreed in principle that if the value of PI of an element is greater than 1.0, it implies that the contamination of the sample by the element is high and may be toxic at the level it is present in the sample [22].

Geoaccumulation index I_{geo} values for the elements was also calculated using the equilibrium equation $\{I_{\text{geo}} = \text{Log}_2(C_n/1.5B_n)\}$ according to Diatta et al. [8] and background levels of elements in noncontaminated soils as reported by IUGS/IAGC [23]. Where C_n is the measured mean concentration of the element in the soil samples; B_n is the background value; 1.5 is the background matrix correction factor due to lithogenic effects. Similar to PI, this will confirm the degree of pollution of the soils.

The t-test was calculated using Microsoft Excel. The data were analyzed using t-test to know whether there was significant difference between the concentrations of elements in the soil and food flour samples. Level of parameter was considered *significant* if t-test value was <0.05.

Cross-plot analysis was carried out in this study to establish interelemental relationship between the contaminated soil and food flour, which will indicate that potential toxic element contamination of the soil and food flour could have originated from the same source namely vehicle emission and also to assess the level of accumulation of the potential toxic elements from the contaminated soil by the food flour as a result of fugitive dusts from the contaminated soils.

The cluster analysis was carried out using the furthest neighbor (complete linkage) grouping of the hierarchical cluster analysis in the statistical package for social scientist (SPSS) package. This was carried out for the analyzed elements in contaminated soil and cassava flour samples in order to establish which elements have chemical affinity and/or similar genetic origin.

The elemental concentrations of the analyzed soil and cassava food samples were also subjected to statistical analysis to determine the Pearson correlation matrix of the elements. This was calculated using statistical package for social scientist (SPSS) and correlation was considered significant at the 0.05 level (2-tailed). This was to further corroborate the cluster analysis.

4. Result and Discussion

The results of the analysis of IAEA reference materials Soil-7 and RF10C are presented in Tables 1 and 2, respectively, together with the certified values of elemental concentrations of the reference materials. The results obtained were in good

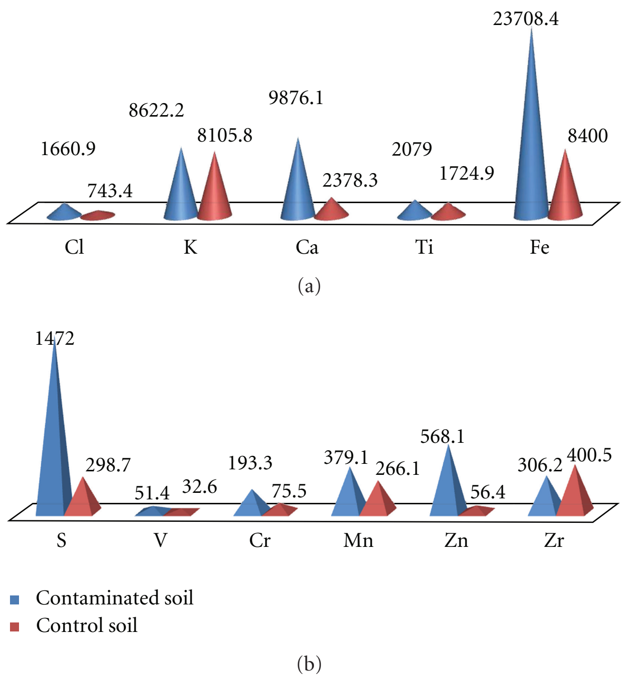

Figure 3: (a) Frequency distribution of the elemental concentrations of the soil samples (μg/g). (b) Frequency distribution of the elemental concentrations of the soil samples (μg/g).

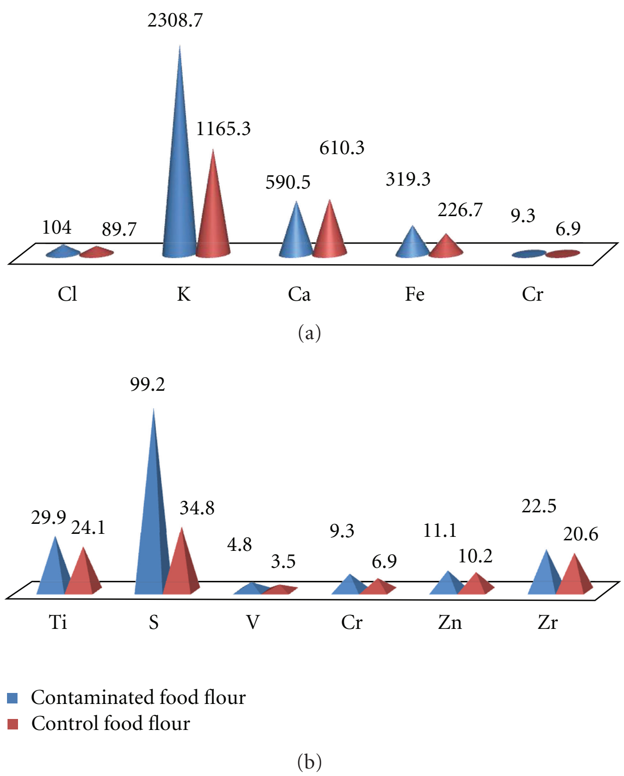

Figure 4: (a) Frequency distribution of the elemental concentrations of the cassava flour samples (μg/g). (b) Frequency distribution of the elemental concentrations of the cassava flour samples (μg/g).

Table 1: IAEA reference material Soil-7 Analysis (μg/g).

Element (μg/g)	This study	Certified value
K	9674.3	9680
Ca	130498.1	130400
Ti	2410.2	2400
V	79.7	53.0
Cr	52.0	48.0
Mn	586.3	505.0
Fe	20572.6	20560.0
Zn	82.1	83.0
As	10.6	10.7
Rb	40.7	40.8
Sr	86.4	86.4

Table 2: NIES reference material RF10C Analysis (μg/g).

Element (μg/g)	This study	Certified value
P	3346.1	3350.0
Cl	217.1	230.0
K	2755.6	2750.0
Ca	96.0	95.0
Mn	39.3	40.1
Fe	10.8	11.4
Cu	4.8	4.1
Zn	23.6	23.1
Rb	5.6	5.7

agreement with the certified values, confirming the reliability of the results acquired.

The frequency distributions of elemental concentrations of the contaminated soil and control soil samples are shown in Figures 3(a) and 3(b). Eleven elements—Cl, K, Ca, Ti, Mn, Fe, S, V, Cr, Zn, and Zr—were detected and their concentrations established. It is observed from the frequency distributions that Fe with range value (7797.2–34537.4 μg/g) and mean value (23708.4 μg/g) had comparably highest concentrations, while Cr had the least value with range value 120.7–300.2 μg/g and average value of 193.3 μg/g. The high value of Fe was not unexpected because the Southwestern Nigeria soils are known to be rich in Fe [24, 25] coupled with the fact that Fe is a vehicle wear metal and most vehicular parts are made up of Fe [26]. It is also noted that the contaminated soils contained higher concentrations of all the analyzed elements than the control soils, indicating that the test soils were indeed influenced by anthropogenic activities. Similar to the results (Figures 4(a) and 4(b)) of the soil analysis, contaminated cassava food flours contained higher levels of the analyzed elements (except Ca) than the control food flours. The similar trend of these results to the results of soil analysis might also be attributable to anthropogenic influences.

Presented in Figures 5(a) and 5(b) are the frequency distributions of elemental concentrations of the contaminated and control cassava food flour samples. The results indicated that K had the highest mean concentrations among

Table 3: Comparison of the analyzed parameters in the contaminated soil samples with other Nigerian and British soils.

Element (μg/g)	Nigerian soils This study (mean and range)	Nigerian soils Olajire and Ayodele [10] (mean and range)	British (M6) motorway soil [27]
S	495.1–2209.2 (1472)	N.A	N.A
Cl	371.8–3376.5 (1660.9)	N.A	N.A
K	3888.2–12042.8 (8622.2)	N.A	N.A
Ca	3803.9–20485.8 (9876.1)	N.A	N.A
Ti	787.6–3943.8 (2079)	N.A	N.A
V	26.6–84.6 (51.4)	N.A	21.3
Cr	120.7–300.2 (193.3)	22.4–63.6 (45.32)	679.8
Mn	282.6–528.0 (379.1)	97.1–386 (172)	885.9
Fe	7797.2–34537.4 (23708.4)	1790–4424 (2541)	57000
Zn	226.0–1093.1 (568.1)	54.8–125 (95.2)	1421.9
Zr	88.4–625 (306.2)	N.A	N.A

Table 4: Comparison of the concentrations of the analyzed elements in the soils with their standard permissible levels.

Element (μg/g)	This study	Excessive level [29]	Tolerable limits [30]	Geochemical baseline [23] (minimum value)	PI value	I_{geo} value	EF value
S	1472.0	N.A	N.A	50.0	29.4	5.9	3.51
Cl	1660.9	N.A	N.A	N.A	—	—	7.93
K	8622.2	N.A	N.A	260.0	33.2	6.7	2.55
Ca	9876.1	N.A	N.A	260.0	38.0	7.6	0.150
Ti	2079.0	N.A	N.A	210.0	9.9	2.0	0.230
V	51.4	N.A	100.0	2.7	19.0	3.8	0.200
Cr	193.3	5.0–50.0	100.0	3.0	64.4	12.9	1.20
Mn	379.1	1500.0	N.A	40.0	10.0	1.9	0.248
Fe	23708.4	N.A	N.A	700.0	33.9	6.8	0.359
Zn	568.1	N.A	100.0	3.0	189.4	38.0	3.13
Zr	306.2	N.A	N.A	5.00	61.2	12.9	1.00

* N.A: not available.

the elements both in test (2308.7 μg/g) and control (1165.3 μg/g) samples, while V had the least values in contaminated (4.8 μg/g) and control (3.5 μg/g) samples.

Table 3 compares the results of the soils with other Nigerian-high way contaminated soils [10] and British (M6) motorway soils [27]. The results revealed that concentrations of Cr (193.3 μg/g), Mn (379.1 μg/g), Fe (23708.4), and Zn (568.1 μg/g) were higher in our study than the contaminated roadside soils investigated by Olajire and Ayodele [10]. Comparison of the results with British (M6) motorway studied by Ward [27] showed that V concentration (51.4 μg/g) was comparably higher in this study, while Cr, Mn, Fe, and Zn values were less.

Comparison of the values of the elements in the contaminated soil samples with their standard permissible limits (Table 4) showed that the concentrations of all the elements (except Cl whose value was not available) were higher than their geochemical baseline values [23]; while the concentrations of Cr and Zn were above their tolerable limits. This was corroborated with the elevated PI and I_{geo} values for the elements, suggesting that the anthropogenically derived contaminations of the soils were significant. Based on the calculated I_{geo}, the soils were moderately polluted with Mn (I_{geo} = 1.9); moderately polluted to heavily polluted with Ti (I_{geo} = 2.0); heavily polluted with V (I_{geo} = 3.8); very heavily polluted with S (I_{geo} = 5.9), K (I_{geo} = 6.7), Ca (I_{geo} = 7.6), Cr (I_{geo} = 12.9), Fe (I_{geo} = 6.8), Zn (I_{geo} = 38.0), and Zr (I_{geo} = 12.9). The EF values for the elements were calculated using Zr as reference element and the elemental concentrations of reference crust from Brady [19]. Chlorine, S, and Zn had EF values greater than 3; implying contamination of the soils with respect to the elements [28].

The t-test value (0.038) for the elemental composition of the contaminated soils and cassava flours using the averages of their analyzed elements as variables is considered *significant*; (<0.05) and this is due to the considerably higher concentrations of the elements in the soils than the cassava flours.

The result of the cross-plot analysis for the contaminated soil and cassava four samples using their elemental average concentrations as variables is presented in Figures 6. Moderate positive correlation (R^2 = 0.426) existed between the two

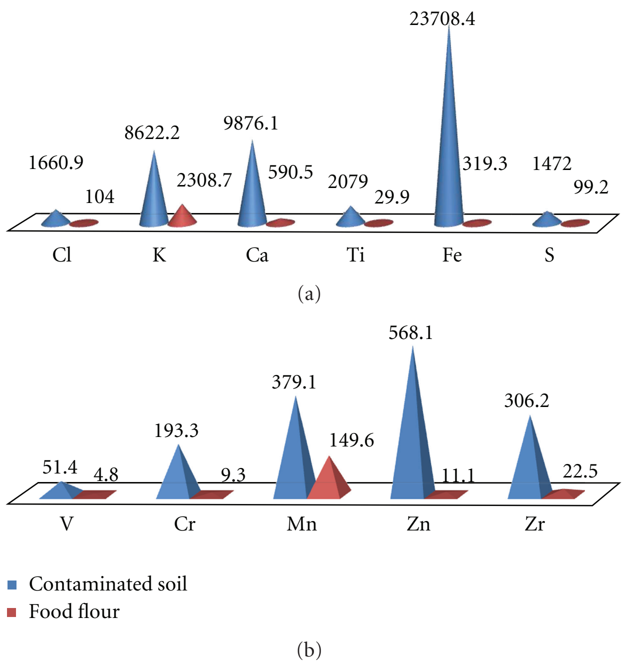

FIGURE 5: (a) Frequency distribution of the elemental concentrations of the contaminated soil and cassava flour samples (μg/g). (b) Frequency distribution of the elemental concentrations of the contaminated soil and cassava flour samples (μg/g).

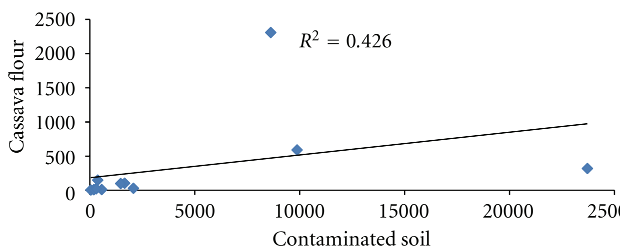

FIGURE 6: Cross plot of the contaminated soil and cassava flour samples using elemental average concentrations (μg/g) as variables.

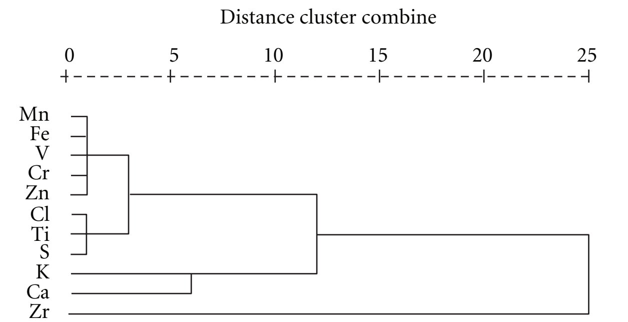

FIGURE 7: Cluster Analysis of the analyzed elements in the soil samples.

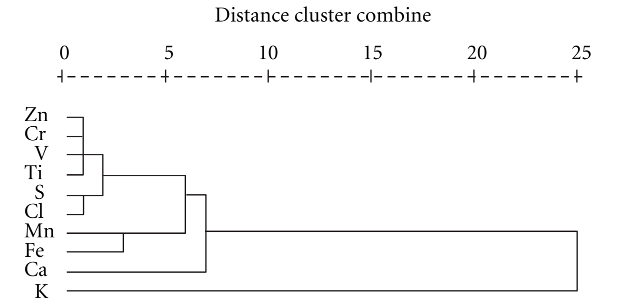

FIGURE 8: Cluster Analysis of the analyzed elements in the cassava flour samples.

sets of samples. The positive correlation indicated interelement relationship between the samples; suggesting a common source of contamination of the soils and food flours. There was also the likelihood that the food flour could have accumulated the potential toxic elements from the contaminated soil via fugitive dusts.

Figure 7 presents cluster analysis results for the elements in the contaminated soil samples. On the X-axis of the dendrogram is the similarity matrix using Euclidean distance, while on the Y-axis are listed the analyzed elements. The results indicated that Mn, Fe, V, Cr, Zn, Cl, Ti, and S exhibit the closest interelement clustering but all the elements were also fairly correlated. This was corroborated by the results of Pearson correlation matrices for the elements presented in Table 5. Similar to cluster analysis results, it is observed from the table that many of the elements showed strong and positive correlation, but the following coupled elements, namely, Ca/Cl (r = .968), Ti/S (r = .898), Ti/Cl (r = .977), Ti/Ca (r = .993), V/Cl (r = .895), Mn/Cl (r = .958), Mn/Ca (r = .942), Mn/Ti (r = .958), Mn/V (r = .890), Fe/Cr (r = .941), Zn/Cr (r = .937), Zn/Fe (r = .892), Zn/Cl (r = .953), Zn/V (r = .978), and Zr/Mn (r = .891) had strong, positive and *significant* correlations. The cluster analysis and Pearson correlation matrices results indicated that the elements had chemical affinity and/or were from similar sources. For instance, Mn, V, Cr, Zn, Ti, and Fe are transition metals having variable oxidation states, while Fe, Cr, Zn, and S are pollutants from vehicular emissions.

Figure 8 shows clustering analysis results for the elements in the contaminated cassava flour samples. On the X-axis of the dendrogram is the similarity matrix using Euclidean distance, while on the Y-axis are listed the analyzed elements. The results indicated three major groups (Zn, Cr, V, Ti, S, Cl, Mn, and Fe); (Ca and Cl); (K) that showed very close interelement clustering; while all the elements were just fairly correlated. This was supported by the results of Pearson correlation matrices for the elements presented in Table 6. Comparable to clustering analysis results, it is noted from the table that many of the elements showed strong and positive correlation, but the following coupled elements, namely, V/S (r = .910), V/Ti (r = .894), Zn/Fe (r = .995), Cr/Ti (r = .979), and Cr/Fe (r = .913) had strong, positive, and *significant* correlations. The cluster analysis and Pearson correlation matrices results confirmed that most of the elements had chemical affinity and/or similar sources as explained previously. These results followed the same trend as that of the contaminated soils and supported their cross plot analysis

Table 5: Pearson correlation matrix of the analyzed elements in the contaminated soils (μg/g).

	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Zn	Zr
S	1.000										
Cl	**.871**	1.000									
K	.102	.221	1.000								
Ca	**.871**	**.968**	.397	1.000							
Ti	**.898**	**.977**	.290	**.993**	1.000						
V	.617	**.895**	.069	**.778**	**.788**	1.000					
Cr	.055	.319	−.448	.230	.298	.438	1.000				
Mn	**.766**	**.958**	.184	**.942**	**.958**	**.890**	.537	1.000			
Fe	.735	**.815**	−.341	.714	.786	**.770**	**.941**	**.857**	1.000		
Zn	−.209	.053	−.346	.022	.073	.156	**.937**	.324	**.892**	1.000	
Zr	.729	**.953**	.209	**.874**	**.873**	**.978**	.305	**.891**	.741	.024	1.000

Table 6: Pearson correlation matrix of the analyzed elements in the cassava food flours (μg/g).

	S	Cl	K	Ca	Ti	V	Mn	Fe	Zn	Cr	Zr
S	1.000										
Cl	−.004	1.000									
K	.379	.868	1.000								
Ca	.639	.104	.104	1.000							
Ti	.656	.006	.485	.210	1.000						
V	**.910**	−.115	−.600	−.399	**.894**	1.000					
Mn	−.120	−.476	−.540	−.712	.158	.100	1.000				
Fe	−.023	−.475	.492	−.668	.568	.543	**.995**	1.000			
Zn	.371	−.029	.118	−.458	.363	.520	.743	**.896**	1.000		
Cr	.546	.149	.589	.118	**.979**	**.801**	.279	**.913**	.266	1.000	
Zr	.623	.294	.426	**.815**	**.852**	.534	.396	.547	.084	.502	1.000

results; indicating that the soils and cassava flours were contaminated via similar sources.

5. Conclusion/Recommendation

This study examined potential toxic elements in soils and food flours along a highway using PIXE spectrometry technique. Similar to the results of the soils, the cassava food flours contained elevated concentrations of the detected elements. The similarity in trend is attributable to anthropogenic influences. Comparison of the results with other countries' soils indicated that the soils contained higher levels of some of the analyzed elements. Comparison of the values of the elements in the contaminated soil samples with their standard permissible limits showed that all the concentrations of all the elements were higher than their geochemical baseline values, while the concentrations of Cr and Zn were above their tolerable limits. This was corroborated by the elevated E.F, PI, and I_{geo} values for the elements, suggesting *significant* anthropogenic contributions to the elemental concentrations of the soils. The t-test value (0.038) for the elemental composition of the contaminated soils and cassava flours was *significant*, apparently because of the considerable higher concentrations of the elements in the soils than the cassava flours. The result of the cross plot analysis for the contaminated soil and cassava four samples using their elemental average concentrations as variables showed moderate positive correlation ($R^2 = 0.426$) between the two sets of samples. The positive correlation indicated interelement relationship between the samples; suggesting that potential toxic element contamination of the soil and food flour could have originated through similar sources and also showed that the food flour could have accumulated some of the potential toxic elements from the contaminated soil through fugitive dusts from the contaminated soils. Cluster analysis results for the elements in the contaminated soil samples showed that Mn, Fe, V, Cr, Zn, Cl, Ti, and S had closest interelement clustering; however all the elements were also fairly correlated. This was corroborated by the results of Pearson correlation matrices for the elements. Cluster analysis results for the analyzed elements in the contaminated cassava flour samples indicated three major groups (Zn, Cr, V, Ti, S, Cl, Mn, and Fe); (Ca and Cl); (K) that showed closest interelement clustering. This was supported by the results of Pearson correlation matrices for the analyzed elements. The cluster analysis and Pearson correlation matrices results confirmed that most of the elements had chemical affinity and/or similar sources. The cross-plot analysis and Pearson correlation matrices results showed that the contaminated soils and cassava flours had interelement relationship indicating contamination via similar sources such as vehicular emissions.

The article provides insight about the consequences of spreading of food stuff for sun-drying along highways.

The elevated levels of these elements reported may cause ill-health. Since sun-drying of food materials along the highway may result in the accumulation of potential toxic elements by the food stuff, it is recommended that people must be aware of the consequences of spreading their food stuff for drying along highways and must be discouraged, an indirect heating such as using oven should be encouraged.

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