Asian Journal of Water, Environment and Pollution

Volume 1 Number 1 & 2 **July – December, 2004**

Contents

Asian Journal of Water, Environment and Pollution, Vol. 3, No. 1, pp. 7-11.

Identification of Contamination Sources of an Urban Grown Vegetable Using Factor and Cluster Analyses

F.S. Olise*, O.K. Owoade and H.B. Olaniyi
Environmental Research Laboratory
Department of Physics, Obafemi Awolowo University, Ile-Ife, Nigeria
✉ felix_rsh@yahoo.co.uk

Received November 23, 2004; revised and accepted December 10, 2005

Abstract: Receptor models, Principal Component Factor Analysis (PCFA) and Hierarchical Cluster Analysis (HCA) were used to determine the number and nature of sources involved in the contamination of vegetables *Amaranthus Spinosus* (Linn Species) grown on swampy plots in an urban town of Ile-Ife, southwest Nigeria. The data set from the elemental characterization of the vegetable samples, earlier reported, was best described by two sources: motor vehicle and entrained road dust/soil, grouped as a source. These analyses in addition to the results of enrichment factor and inter-elemental correlation analyses provide information on the source types impacting the receptors-vegetables. The need for legislative intervention in the prohibition of growing food crops especially vegetables in urban centres is recommended.

Introduction

Amaranthus Spinosus (Linn specie) of vegetables, popularly called *Green* in most parts of Nigeria, is a common household food item. It is grown across season in farmlands far away from towns and cities' centres during rainy season and, mostly, on swampy plots in urban centres during the dry season. The urban grown vegetables, which dominate the market during the dry seasons, are treated with waters from streams and shallow wells. The sources of the irrigation water also serve as source of water for *Carwash Centres*. The irrigation system is therefore prone to contamination from fuel, grease and detergents and other reagents in use by the car wash operators. Also, the irrigation system as well as the plots receive large amounts of particulate matter from anthropogenic sources in the form of vehicular emissions, waste burning and improper sewage disposal whose impacts are most noticed during the dry season.

It has been reported that heavy metals contamination of vegetables grown within urban centres could be significant (Owoade et al., 2004). Most of the metallic pollutants are in compound form and they get dissolved in soil water and are subsequently absorbed through the roots so that we talk of serious contaminations through the soil but it has been reported that highest contaminations are associated with those portions of the plant which have the greatest surface to volume ratio, e.g. leaves (Schuck and Locke, 1970). Though research has shown that high proportions of ingested toxic elements are excreted, the populace still faces serious health risks from food poisoning in respect of heavy metals like Pb, Cu, Zn and Cr due to long time accumulation effect (Loppi et al., 1998).

Unfortunately most people involved in the cultivation of this food item are illiterates and the very few of them who are educated believe some of the sources of the contaminants, e.g. refuse, to be manures. An unemployed Agricultural Extension graduate who owns one of the plots used in this study agreed with us on the impacts of various degrees of contamination of the said food item on health but believed that the contaminations are negligibly small, forgetting long-term accumulation effects. In the light of this the actual sources of the

* Corresponding Author

contaminants would need to be ascertained and the populace and the appropriate authorities educated on it.

Materials and Methods

The sampling, preparation and elemental characterization of the vegetable samples have been reported (Owoade et al., 2004). The total reflection x-ray fluorescence technique analysed metals from samples collected at three urban locations were subjected to statistical analyses—correlation matrix, enrichment factor, factor and cluster analyses for identification of possible contributing sources of such metals to their levels in the vegetable samples.

In this work, correlation coefficients of 0.50 and above were taken as significant in view of the dependence of common origin or influencing factor of two variables on high correlation coefficients. The enrichment factor (EF) is the quotient of the ratio of the concentration of element *x* to the concentration of reference element *f* in the vegetable sample to the same ratio in the reference soil. It is expressed as:

$$\mathrm{EF} = \frac{\left(\dfrac{C_x}{C_f}\right)_{veg}}{\left(\dfrac{C_x}{C_f}\right)_{ref.soil}}$$

where C_x and C_f are the concentrations of element *x* and reference element *f* in vegetable and reference soil samples. Elements with enrichment factors greater than four are believed to have significant anthropogenic influences, while enrichment factor less than four means that an element is mainly crustal in origin. Iron was used as normalizing element because it is present in all the samples above detectible limit.

The two methods of multivariate analyses used for the identification of sources in the contamination of the urban grown vegetable in this study are factor analysis and hierarchical cluster analysis. The nature of sources was determined by associating the largest factor loadings with the elemental marker from a particular source. For example, Pb is the marker element for automotive or industrial sources. Detailed descriptions of the model and its applications have been reported elsewhere (Roscoe et al., 1982; Gao et al., 1994; Huang et al., 1999). This model starts with principal component analysis, using the correlation matrix of the elemental concentrations, followed by a VARIMAX rotation. The rotated component loadings in each factor are used to infer potential source/sources. Choosing the number of factors to retain in the analysis was guided by the Kaiser criterion, whose rule is to drop all components with eigenvalues less than unity (Harrison et al., 1997). Hierarchical cluster analysis (CA) was used to arrange each sample into a cluster pattern giving an indication of the relationship between individual samples. A set of clusters was established such that cases within a cluster are more similar to each other than they are to cases in other clusters. The task, therefore, is to group observations (objects) that are close enough or have the same origin together as a cluster (Spyrou et al., 1992; Wongphatarakul et al., 1998). The result is best described in the form of a dendrogram or binary tree, where the observations are represented as a node in the dendrogram and the branches illustrate when the subgroups containing those observations are joined. The divisive option of the hierarchical cluster analysis method was used in this work. The method employed Euclidean distance and complete linkage (Furthest neighbour) as a measure of correlation. The combination of these two methods was shown to be a powerful tool for relating a large set of elemental concentrations to their possible sources without prior assumptions as to the number or nature of the sources. The correlation matrix, factor and cluster analyses were carried out using SPSS 10.0 for windows statistical package.

Results and Discussion

The inter-elemental correlation matrix for the data set obtained from each of the three sites is shown in Tables 1 to 3. In site 1, titanium correlated well with Mn, Fe, Cu and Pb (0.67, 0.79, 0.64 and 0.93 respectively). Copper had correlation coefficients of 0.73, 0.92, 0.62, 0.65, 0.67 and 0.89 with Ca, Mn, Cr, Zn, Br and Pb respectively while those of Pb with Cr, Fe, Zn and Br were 0.63, 0.81, 0.94 and 0.95 respectively. It was observed that the correlation coefficients generated for the elements detected in samples from the other two sites (Sites 2 and 3) were similar to those from Site 1, both in terms of elemental species and coefficients. This may suggest similar pattern of impaction of the vegetable plots in respect of the metals involved.

Table 4 shows the enriched elements detected in vegetable and soil samples. It was observed that Cr, Mn, Br, Sr and Pb were highly enriched in the vegetable samples while only Sr and Pb were enriched in the soil samples, taking EF $\geq$ 5 as indication of possible anthropogenic influence. These metals high enrichments

Table 1: Inter-Elemental Correlation Matrix for Site 1

	K	*Ca*	*Ti*	*Cr*	*Mn*	*Fe*	*Cu*	*Zn*	*Br*	*Rb*	*Sr*	*Pb*
K	1.000											
Ca	–.554	1.000										
Ti	.212	–.218	1.000									
Cr	.156	–.689	–.480	1.000								
Mn	–.316	.520	**.685**	–.584	1.000							
Fe	–.269	–.177	**.791**	.183	.554	1.000						
Cu	–.581	**.729**	**.644**	–.788	**.923**	.448	1.000					
Zn	–.610	**.891**	–.112	**.615**	.321	.380	**.654**	1.000				
Br	.527	.158	.116	–.232	.487	–.333	**.673**	**.656**	1.000			
Rb	.430	.191	.493	–.463	–.255	.361	.127	.397	–.564	1.000		
Sr	.346	**.669**	.165	–.655	.590	–.253	.460	.184	**.656**	.279	1.000	
Pb	.279	–.243	**.931**	**.632**	.206	**.806**	**.889**	**.937**	**.953**	–.766	.325	1.000

Table 2: Inter-Elemental Correlation Matrix for Site 2

	K	*Ca*	*Ti*	*Cr*	*Mn*	*Fe*	*Cu*	*Zn*	*Br*	*Rb*	*Sr*	*Pb*
K	1.000											
Ca	–.444	1.000										
Ti	.102	–.198	1.000									
Cr	.046	–.579	–.370	1.000								
Mn	–.206	.410	**.575**	–.474	1.000							
Fe	–.159	–.067	**.681**	.073	.444	1.000						
Cu	–.471	**.619**	**.534**	–.678	**.813**	.338	1.000					
Zn	–.500	**.781**	-.002	**.505**	.211	.270	**.544**	1.000				
Br	.417	.048	.006	–.122	.377	–.223	**.663**	**.646**	1.000			
Rb	.320	.081	.383	–.353	–.145	.251	.017	.287	–.454	1.000		
Sr	.236	**.559**	.055	–.545	.480	–.143	.350	.074	**.546**	.169	1.000	
Pb	.169	–.133	**.821**	**.522**	.096	**.696**	**.779**	**.827**	**.843**	–.656	.215	1.000

Table 3: Inter-Elemental Correlation Matrix for Site 3

	K	*Ca*	*Ti*	*Cr*	*Mn*	*Fe*	*Cu*	*Zn*	*Br*	*Rb*	*Sr*	*Pb*
K	1.000											
Ca	–.544	1.000										
Ti	.202	–.298	1.000									
Cr	.146	–.679	–.470	1.000								
Mn	–.306	.510	**.675**	–.574	1.000							
Fe	–.259	–.167	**.781**	.173	.544	1.000						
Cu	–.571	**.719**	**.634**	–.678	**.913**	.438	1.000					
Zn	–.500	**.881**	-.102	**.605**	.311	.370	**.644**	1.000				
Br	.517	.148	.106	–.222	.477	–.323	**.763**	**.726**	1.000			
Rb	.420	.181	.483	–.353	–.145	.351	.117	.387	–.454	1.000		
Sr	.336	**.659**	.155	–.545	.580	–.243	.450	.174	**.646**	.269	1.000	
Pb	.269	–.233	**.921**	**.622**	.196	**.796**	**.879**	**.927**	**.943**	–.656	.315	1.000

Table 4: Enriched Elements Detected in Vegetable and Soil Samples

		Elements				
		Cr	*Mn*	*Br*	*Sr*	*Pb*
Site 1	Soil	-	-	-	13.4	46.2
	Leaf	13.65	6.55	3517.8	26.55	622.17
	Stem	56.61	4.71	10107.8	43.16	2928.7
	Root	8.45	2.34	1089.6	15.51	136.6
Site 2	Soil	-	-	-	12.9	37.9
	Leaf	39.64	6.12	2297.1	25.88	468.7
	Stem	184.4	5.51	6322.7	88.82	1374.7
	Root	72.08	3.51	1014.4	21.24	1070.6
Site 3	Soil	-	-	-	14.2	182.5
	Leaf	21.18	5.75	1765.2	47.6	556.5
	Stem	61.94	2.61	2008.2	51.11	514.7
	Root	25.89	2.61	748.1	14.33	208.7

from the vegetable and soil samples are attributable to strong impactions from wind and automobiles related re-entrained particulates that settle soon after re-entrainment.

The factor analysis result returned three factors that met the Kaiser criterion for each of the three sites. For Site 1, factor 1 has a variance of 6.62 and accounts for 39.20% of the total system variance. It is loaded in Ti, Cr, Mn, Sr and Rb. Titanium and Mn are correlated while Cr, Mn and Sr are enriched. We suggest that this factor represents contribution from soil noting that these elements are crustal in nature. Factor 2 has a variance of 5.24 and accounts for 37.11% of the total system variance. It is loaded in Br, Zn, Cu and Pb. All these elements are highly correlated and Pb and Br are highly enriched. This factor suggests contributions from automobile or related sources since these elements are marker elements for automobile in the absence of industrial contributions. Factor 3 has a variance of 2.23 and accounts for 13.72% of the total system variance. It is loaded in Fe, Ca and K. These lithophilic elements are neither correlated nor enriched and this factor is, therefore, concluded to be entrained soil particles source. The total variance explained is the cumulative variance (39.20 + 37.11 + 13.72), which equals 90.03% (80% being the optimum). Like the correlation matrix analysis, each of the three factors resolved in Sites 2 and 3 had similar variance (eigen value) and total system variance explained for Site 1 except that factor 3 of Site 2 contains Ti instead of Fe in factor 3 of Site 1; and factor 3 of Site 3 contains Mn and Ti in addition to Fe and K in factor 3 of Site 1.

The result of the cluster analysis for each of the three sites is shown in Figures 1 to 3. The result complements

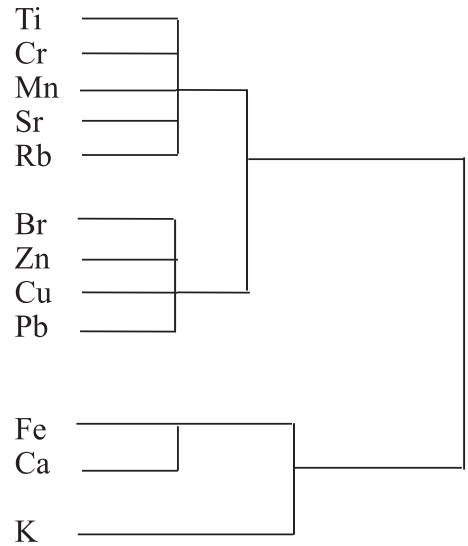

Figure 1: Site 1 Cluster analysis result.

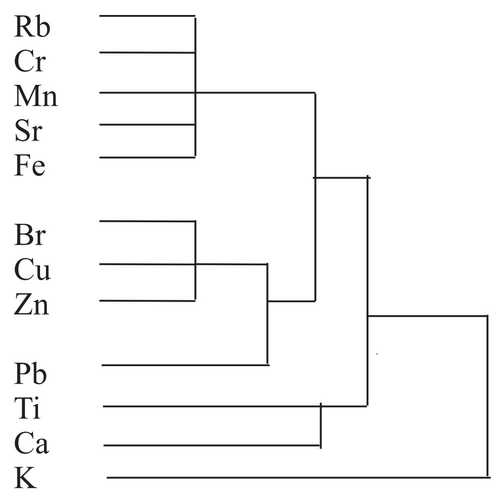

Figure 2: Site 2 Cluster analysis result.

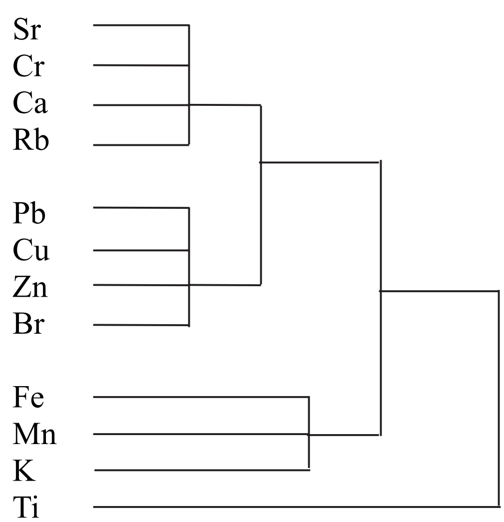

Figure 3: Site 3 Cluster analysis result.

those of the correlation matrix, enrichment factor and factor loadings. The highly correlated elements—Br, Zn, Cu and Pb, which are also resolved as factor 2 for all the three sites—are observed grouped together as second cluster for the three sites. The cluster analysis also confirmed the grouping of other elements into factors 1 and 3 for all the three sites confirming the suggested sources of contamination.

Conclusion

The multivariate principal factor and cluster analyses together with the results of elemental correlations and enrichment factor analyses have been used to identify the principal route of contamination of vegetables grown within urban centres. The metals resolved in a factor believed to represent automotive source might also have impacted the irrigation water and hence the receptors (vegetables) through the carwash route. It is therefore imminent that cultivation of food items on plots prone to all forms of particulate impaction and irrigation water contamination should be discouraged. The local sanitary inspectors as well as the department of environmental issues in local governments are encouraged to see to the discontinuation of this practice.

References

Gao, N., Cheng, M.D. and P.K. Hopke (1994). Receptor Modeling for Airborne Ionic Specie Collected in SCAQS, 1987. *Atmo. Envmt*., **28:** 1447-1470.

Harrison, R.M., Deacon, A.R., Jones, M.R. and R.S. Appleby (1997). Sources and Processes Affecting Concentration of PM_{10} and $PM_{2.5}$ Particulate Matter in Birmingham, UK. *Atmo. Envmt*., **31:** 4103-4117.

Huang, S., Rahn, R.A. and R. Arimoto (1999). Testing and Optimizing Two Factor Analysis Techniques on Aerosol at Narragansett, Rhode Island. *Atmo. Envmt*., **33:** 2169-2185.

Loppi, S., Pacioni, G., Olivieri, N. and Di Giacomo (1998). Accumulation of trace metals in the lichen *Evernia prunastri* transplanted at biomonitoring sites in central Italy. *Bryologist*, **101(3):** 451-454.

Owoade, O.K., Olise, F.S. and H.B. Olaniyi (2004). Assessment of Trace Metals Composition of Vegetable *Amaranthus Spinosus* (Linn Species) Grown along Urban Motorways Using TXRF Technique. *Ife Journal of Science*, **6(1):** 45-49.

Roscoe, B.A., Hopke, P.K., Dattner, S.L. and J.M. Jenks (1982). The Use of Principal Component Factor Analysis to Interpret Particulate Compositional Data Set. *J. Air Poll. Contrl. Asso*., **32(6):** 637-647.

Schuck, E.A. and J.K. Locke (1970). Relationship of automotive lead particulates to certain consumer crops. *Environmental Science and Technology*, **4(4):** 324-330.

Spyrou, N.M., Arshed, W., Farooqi, A.S., Ibeanu, G.I., Akanle, A.O., Jaynes, C., Asubiojo, I.O., Obioh, I.B., Oluyemi, E.A. and A.F. Oluwole (1992). Usefulness of Nuclear and Atomic Based Techniques in Air Pollution Studies in Nigeria. *J. Radioanal. Nucl. Chem*., **161(1):** 189-199.

Wongphatarakul, V., Friedlander, S.K. and J.P. Pinto (1998). A Comparative Study of PM 2.5 Ambient Aerosol Chemical Database. *Envmtl. Sci. Technl*., **32(24):** 3926-3934.