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Application of Multivariate Statistics for the Identification of Possible Sources of Metal Elements in Soil of Waste Disposal Site in Khulna

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A B S T R A C T

The main focus of present study was to demonstrate the possible generation sources of metal contamination in soil. The only authorized waste disposal site at Rajbandh located at Khulna in Bangladesh. To this endeavors, total sixty soil samples were collected at a depth of 0-30 cm from the existing ground surface and the relevant metal elements of Al, As, Ba, Ca, Cd, Cr, Co, Cu, Fe, Hg, K, Mn, Na, Ni, Pb, Sb, Sc, Sr, Ti, V and Zn were measured through standard methods in laboratory. Desired results for normality test obtained from normal QQ plot using XLSTAT. Almost all the metal elements were normally distributed in both the seasons. Multivariate statistics such as Pearson's correlation, principal component analysis (PCA) and agglomerative hierarchical clustering (AHC) were performed using XLSTAT to show the correlation between metal elements and their possible generation sources. Results of multivariate statistics revealed that almost all the metal elements were strongly correlated indicating same generation sources. In addition, results of PCA and AHC depicted that almost all the metal elements in soil derived from anthropogenic/human activities; least number of metal elements from natural sources as well as from both the natural and anthropogenic sources. Proper identification and control of possible generation sources of metal elements may reduce the threat of soil contamination due to metal elements in waste disposal site.

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INTRODUCTION

Changes in consumption pattern of population have changed the generation of municipal solid waste (MSW) from households and commercial areas than ever before. Different biological, physical and chemical processes as well as due to the emission of toxic metal element from MSW, leachate and contaminated soil create vulnerable to the environmental components such as water, soil and nearby inhabitants [1]. The sources of metal elements are either natural parent rock materials or anthropogenic activities such as urban-industrial development, landfill management, vehicular emissions, fossil fuel combustion and agricultural practices also influence metal element contents in soil [2].

The term "landfill" refers to an engineering unit, designed and operated for the disposal of municipal solid waste (MSW) in a systematic way. Although there are many alternative options of waste disposal, open dumping is the main disposal method of MSW in developing countries like Bangladesh [3]. Multivariate statistical analysis aimed at describing how the variables are related to one another, and how they work in combination to distinguish between the cases on which the observations are made. In principal component analysis (PCA), the principal components (PCs) with variables, the high loadings (eigenvalues) depicted greater importance from the contamination sources [4]. Agglomerative Hierarchical Clustering (AHC) is an iterative classification method subjected to classify the data into groups of similarity (clusters) in form of the hierarchical dendrograms [5].

Khulna is the third largest metropolitan city of Bangladesh. Total rate of MSW generation in Khulna is found to be 420 to 520 ton per day, directly disposed at Rajbandh waste disposal site which is the only official dumping site over 25 acres in area [6]. The waste disposal site is 10 kilometers far from City Corporation headquarter in the direction of west. Unplanned and uncontrolled MSW disposal arise the necessity to carry out an intensive study of possible generation sources of such pollution on in and around the disposal site. The distribution of the concentration of metal elements was described using conventional statistics such as mean, maximum, minimum, median, standard deviation (SD), co-efficient of variation (CV), skewness and kurtosis by using Statistical Package for the Social Sciences (SPSS). Multivariate statistical analyses such as Pearson's correlation, PCA and AHC were performed using

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XLSTAT to determine how the metal elements are correlated to each other as well as their possible sources of contamination such as anthropogenic or human activities and natural parent materials. The main purposes of this study are (i) to perform the correlation between metal elements and (ii) to identify the generation sources of metal elements.

MATERIAL AND METHODS

The total research procedure and materials utilized in this study are described in the following articles.

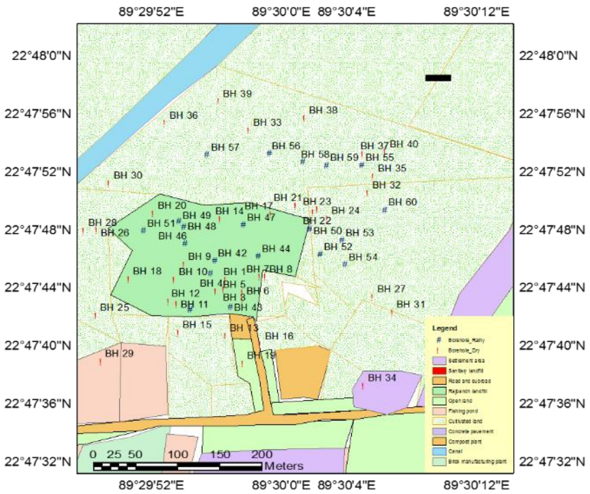

Figure 1. Map showing of soil sampling locations in waste disposal site.

Study Area

Khulna is the third established metropolitan city located in the khulna division of Bangladesh. It covers an area of 4394.45 km² and is bordered on the north by the Jessore district and the Narail district, on the south by the Bay of Bengal, on the east by the Bagerhat District, and on the west by the Satkhira district. The geological location of Khulna is 22.35^0N and 89.30^0E. Urban development results a huge amount of waste generation poses a great thread to the environment and human health. The selected waste disposal site, Rajbandh is the only certified waste dumping site of Khulna. Based on aforementioned authenticities, it has become inevitable of comprehensive study of possible generation sources of metal elements in soils to minimize their spread over the study area.

Soil Sampling

In total sixty soil samples, forty samples were collected in dry season (March to May 2016) then rest twenty samples were collected in rainy season (June to August 2016). In dry season, the first sampling point referred as BH-1 was at the center of waste disposal site followed by a gradual addition of about 10 m distance by the subsequent boreholes. On the other hand, the first sampling location of rainy season (BH-41) is about 30 m apart from BH-1 maintaining a gradual addition of about 15 m in selecting other following boreholes. Figure 1 depicted the soil sampling locations in waste disposal site at Rajbandh, red circles indicated sampling points in dry season and blue triangles indicated sampling points in rainy season.

Laboratory Investigation

Concentration of relevant metal elements in soil was measured maintaining standard procedure in laboratory. At first 10 g of each soil sample was taken into a 100 mL conical flask washed with deionized water and left overnight. Each sample was kept into the temperature of 150°C for about 90 minutes followed by raising the temperature upto 230°C for 30 minutes. Subsequently, re-digestion of samples was done by adding HCl solution in ratio of 1:1 for another 30 minutes. The mixture obtained was cooled down to room temperature. After performing the digestion procedure, metal element concentrations in this digested solution were determined using atomic absorption spectrophotometer (AAS) and the amount of each heavy metal was deduced from the calibration graph and reported in mg/kg.

Normality Test

In this study, the null distribution of S-W and K–S test was calculated under the null hypothesis that the sample was drawn from the reference distribution considering "95% upper confidence level" principal. When significance value, $p > 0.05$, it can be decided as the data comes from a normal distribution [7]. Normal QQ plot for each metal element was plotted using XLSTAT to evaluate normality as it is not susceptible to sample size. Data points close to 45^0 reference line indicate normal distribution.

TABLE 1. Typical values of Skewness and Kurtosis

Skewness	Type of Skewness	Kurtosis	Type of Kurtosis
-0.5 to 0.5	Approximately symmetrical	<0	Platykurtic distribution
-0.5 to -0.1 and 0.1 to 0.5	Moderately skewed	>0	Leptokurtic distribution
<-1 and > **1**	Highly skewed	=3	Normal distribution

Conventional statistical analysis

Conventional statistical analysis in terms of mean, median, standard deviation (SD), coefficient of variation (CV), skewness and kurtosis was conducted using SPSS 16.0 to describe the distribution and seasonal variation of metal concentration in waste disposal site. Distribution pattern of metal concentrations were identified based on skewness and kurtosis values tabulated in Table 1.

Pearson's correlation

In this study, the value of correlation coefficient, r, was computed using the Equation (1) to measure the intensity of association between two metal elements. Typical correlations based on r value were provided in Table 2.

$$r = \frac{\sum_{i=1}^{n}(x_i-\bar{x})\,(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i-\bar{y})^2}} \qquad (1)$$

TABLE 2. Typical values of Pearson's correlation coefficient (*r* value)

r value	Type of correlation	*r* value	Type of correlation
-1	Negative correlation	0.1~0.3	Weakly correlated
0	No correlation	0.3~0.5	Moderately correlated
1	Positive correlation	>0.5	Strongly correlated

Principal component analysis

In this study, the PCA method was performed sequentially, first by information extraction in the input space (with n-dimensions) to determine the directions of which the input variables display the most substantial variability (Equation 2).

$$PC1 = a_1x_1 + a_2x_2 + \cdots + a_nx_n \qquad (2)$$
$$PCn = \sum_{j=1}^{n} a_{1j}x_j$$

Where, a_{1j}= eigenvectors obtained from the correlation matrix and x_j= input variables

Factor loadings lead to identification of possible generation sources of pollution by metal elements. It seems reasonable to tentatively identify the first rotated factor as "anthropogenic activities" and second rotated factor as "natural sources". Moreover, some previous investigations indicated first principal component (PC1) and second component (PC2) refers to the contamination of soil due to anthropogenic or human activities and natural parent materials, respectively [2].

Agglomerative hierarchical clustering

In order to achieve the goal this series of procedures was maintained in the present study: Normalization of the raw input data> Determination of the distance between the objects of classification by application euclidean distance > Appropriate linkage between the objects (centroid linkage) > Plotting the results as dendrogram >Determination of the clustering pattern.

RESULTS AND DISCUSSION

Heavy metal concentrations in the soils

The outputs of K-S and S-W for all the studied metal elements in soil for both the dry and rainy seasons are provided in Table 3. Considering sensitivity of non-parametric test, it is found from normal QQ plot that almost all the metal elements in soil for both the dry and rainy seasons were distributed normally except As. Thus, log transformation was applied to As for normal distribution.

TABLE 3. Normality test of metal elements in soil

Metal	Dry		Rainy	
	K-S Sig.	S-W Sig.	K-S Sig.	S-W Sig.
Al	0.200*	0.104	0.200*	0.18
As	0	0.001	0	0
Ni	0.200*	0.035	0.200*	0.285
Sb	0.200*	0.076	0.200*	0.398
Ti	0.200*	0.035	0.200*	0.628

*Lower bound of the true significance.

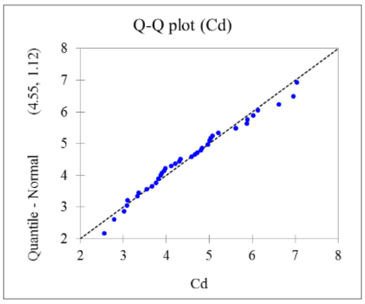

Figure 2. Normal QQ plot of Cd in dry season.

Figure 2 depicts normal QQ plot for Cd in dry season. Results reveal that the CV varied from 22.11% of Zn to 59.41% of Cu in dry season as well as 18.25% of Zn to 77.25% of Mn in rainy season, respectively; which indicates a great degree of variability. The greatest and the smallest SD were detected for metal element of Ti (406.26) and Cd (1.14) in the dry season (Table 4). Similarly, the greatest and the smallest SD were detected for metal element of Ti (297.85) and Cd (0.74) in the rainy season.

Table 4 discloses that metal elements of Al, Cd, Co, K, Na, Ni, Sc and Ti were approximately symmetrical; As, Ba, Ca, Cr, Hg, Sb, Sr, V and Zn were moderately and Cu, Fe, Mn and Pb were highly skewed. In addition, the metal elements of Al, As, Ba, Ca, Cd, Co, Cr, Fe, Hg, K, Na, Ni, Sc, Ti and Zn exhibited platykurtic distribution (Kurtosis<0), whereas the metal elements of Cu, Mn, Pb, Sb, Sr and V exhibited leptokurtic distribution (Kurtosis >0). Moreover, the metal elements of Al, Ba, Co, Fe, Ni, Pb, Sb, V and Zn were fairly symmetrical in rainy season; Ca, K, Mn, Na, Sc, Sr and Ti indicated moderately skewed and As, Cd, Cr, Cu and Hg were highly skewed. Furthermore, the metal elements of Al, Ba, Ca, Co, Fe, K, Mn, Na, Ni, Pb, Sb, Sc, Sr, V and Zn exhibited platykurtic distribution, whereas the metal elements of As, Cd, Cr, Cu, Hg and Ti exhibited leptokurtic distribution.

Seasonal comparison of the concentration of metal elements

The concentrations of metal elements for rainy reason were relatively lower as compared to the dry season and the magnitude of concentrations followed almost same pattern for both the dry and rainy seasons as Fe>Al>K>Ca>Ba>Na>Pb>V>Ti>Sr>Zn>Mn>Sc> Cu>Sb>Co>Cr>Hg>As>Ni>Cd.

Correlation analysis of metal elements

The Pearson's correlation matrix of metal elements in soil for the dry season is provided in Table 5. In dry season, it was observed high positively correlations between Ba and Ca (0.992), Sc and Ti (0.987), Sb and Sc (0.986), Sb and V (0.984), Sc and Ba (0.983), Al and Sc (0.979), Ti and Ba (0.975), As and Al (0.974), V and Ca (0.974), As and Ba (0.970) Ti and Sb (0.966), Ni and Fe(0.927), Zn and V (0.906) as well as Hg and V (0.876) (Table 5).

In addition, strong correlation of metal elements in rainy season indicated same sources of contamination. However, concentration of Cr and Hg in dry and rainy seasons showed comparatively weak correlations with Mn and Zn respectively; indicated different generation sources.

Principal component analysis

For variability calculation based on eigenvector and factor loadings, PCs of 21 for dry and 19 for rainy were considered for the metal element [8]. Based on the results of PCA for metal elements of dry season, the eigenvalues up to the second extracted components (F2) were found greater than 1.0 (Table 6). Thus, the variables could be reduced to 2 components model (dry season) with 92.105% variation (Equation 3).

$$\left(\left\{\sum_{i=1}^{2}\lambda_i\right\}/\left\{\sum_{i=1}^{21}\lambda_i\right\}\right) \quad (3)$$

$$\left(\left\{\sum_{i=3}^{21}\lambda_i\right\}/\left\{\sum_{i=1}^{21}\lambda_i\right\}\right) \quad (4)$$

$$\left(\left\{\sum_{i=1}^{1}\lambda_i\right\}/\left\{\sum_{i=1}^{18}\lambda_i\right\}\right) \quad (5)$$

$$\left(\left\{\sum_{i=2}^{19}\lambda_i\right\}/\left\{\sum_{i=1}^{19}\lambda_i\right\}\right) \quad (6)$$

The eigenvalues λ_i ($\lambda_3, \lambda_4, \dots . \lambda_{19}, \lambda_{20}, \lambda_{21}$), had little contributions to the total structure of 7.895% (Equation 4). This suggested that very little information, which can be considered negligible

However, the percentage contribution of the 1 component model (rainy season) that accounts for 88.253% variation (Equation 5). The % contribution of the 2nd to 19th PCs as illustrated in Equation 7 was 11.75% for rainy season (Equation 6).

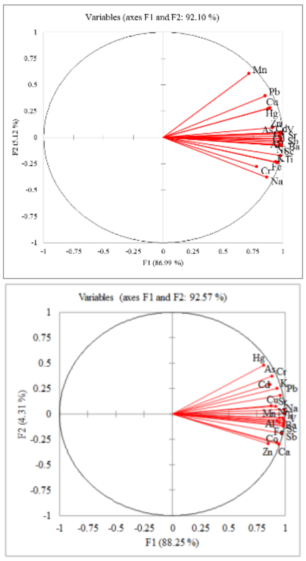

Figure 3. Correlation circle for metal elements in soil (a) dry and (b) rainy season.

Correlation circle shows projection of initial variables in the factor space. In the loading plot corresponding to the first two PCs (Figure 3a); metal elements of Ca, Al, Ti, Sb, Sc, Sr, V and Ba showed clear positive correlation because these metal elements were at a longer distance from origin. Besides, the metal elements of Na, Pb, Cu, K, Ni, Co, Hg, Fe, As, Zn and Cd, which also positively correlated with less stronger impact because they were comparative in shorter distance from origin than that of Ca, Al, Ti, Sb, Sc, Sr, V and Ba. Moreover, the metal element of Mn and Cr having the least impact on the PCA model as they were far from each other. It was noticed that Cu, Hg, Mn, Pb and Zn in soil were located at a distance from origin of circle than that of other metal elements. This indicated the origin of these metal elements was differing from other metal elements. This result is also in agreement with factor analysis. In a same manner, Figure 3b illustrates Ca, Al, Ti, Sb, Sc, Sr, V and Ba in soil showed clear positive correlation but they have stronger impact on the PCA model than that of Na, Pb, Cu, K, Ni, Co, Mn, Fe, As, Cr and Cd and Hg and Zn having the least impact on the PCA model. In this study, varimax rotation was applied to spread the importance more or less evenly between the two rotated factors. In dry season, factor analysis revealed that metal elements of Al, As, Ba, Ca, Cd, Co, Fe, K, Na, Ni, Sb, Sc, Sr, Ti and V were closely related to PC1 indicated derived from anthropogenic activities and rests of the metal elements of Cu, Hg, Mn, Pb and Zn in soil were related to PC2 indicated derived from natural parent materials (Table 7).

In addition, the metal element of Cr was closed to PC1 and PC2 indicated derived from both the anthropogenic activities and natural parent materials. From Table 8, it can be estimated that As, Cr, Hg, K, Mn and Na in soil were related to PC2 indicating derived from natural parent materials. Other metal elements of Al, Ba, Ca, Co, Cu, Fe, Ni, Sb, Sc, Sr, Ti and V were related to PC1 indicating derived from anthropogenic activities.

Agglomerative hierarchical clustering

In dry season, maximum distance to centroid was found for cluster 2 of 170.28 between three clusters, indicating generation of metal elements from natural sources (Table 9). Moreover, maximum distance to centroid for cluster 1 was found comparatively smaller of 122.52 than that of cluster 2, indicating generation of metal elements from anthropogenic or human activities. Cluster 3 showed maximum distance to centroid was zero, indicating it was closed to both the clusters, consequently generated from both natural sources and anthropogenic activities (Table 9).

Cluster 1 comprises with metal elements of Al, As, Ba, Ca, Cd, Co, Fe, K, Na, Ni, Sb, Sc, Sr, Ti and V in soil which indicated these metal elements were generated from anthropogenic activities. In addition, cluster 2 comprises with Cu, Hg, Mn, Pb, and Zn, indicating origination from natural sources and Cluster 3 comprises with Cr which derived from both the natural parent materials and anthropogenic sources (Figure 4a).

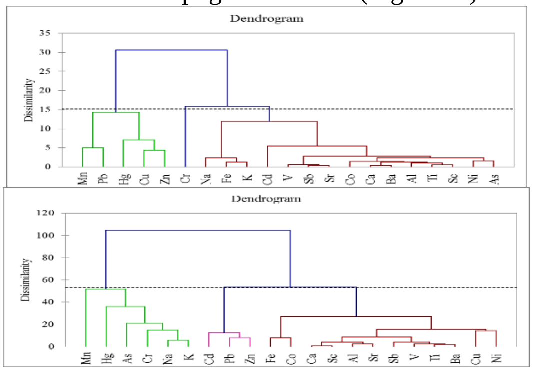

Figure 4. Dendrogram for metal elements in soil during (a) dry and (b) rainy season.

Similarly, for rainy season, cluster 1 comprises with metal elements of Al, Ba, Ca, Co, Cu, Fe, Ni, Sb, Sc, Sr, Ti and V which indicated these metal elements were generated from anthropogenic activities (Table 9). Cluster 2 comprises with As, Cr, Hg, Mn, K and Na indicating origination from natural sources and Cluster 3 comprises with Cd, Pb and Zn which derived from both natural parent materials and anthropogenic sources (Figure 4b). Figure 4 represents the hierarchical dendrograms for the classification of metal elements presence in soil for both the dry and rainy season.

TABLE 4. Descriptive statistics of metal elements in soil for dry season (n=40)

Metal	Min (mg/kg)	Max (mg/kg)	Median (mg/kg)	Mean (mg/kg)	CV (%)	SD	Skewness	Kurtosis
Al	158.35	874.78	458.46	490.25	40.31	197.61	0.303	-0.727
As	1.55	8.77	3.42	4.15	48.79	2.03	0.733	-0.709
Cd	2.55	7.03	4.46	4.55	24.99	1.14	0.387	-0.530
Cu	2.92	16.45	4.82	6.20	59.41	3.68	1.541	1.110
Fe	733.19	1987.7	1386.5	1363.94	25.67	350.15	-0.081	-1.199
Hg	1.98	9.20	4.01	4.63	44.63	2.07	0.797	-0.460
Ti	643.33	1937.3	1223.8	1221.2	33.27	406.26	0.160	-1.198
Zn	22.79	50.76	34.64	34.57	22.11	7.65	0.612	-0.116

TABLE 5. Correlation analysis and coefficients for the metal elements in dry season

	As	Ba	Ca	Cd	Cr	Cu	Fe	Hg	Ni	Pb	Ti	Zn
As	1.00											
Ba	0.970	1.00										
Ca	0.974	0.992	1.00									
Cd	0.892	0.926	0.920	1.00								
Cr	0.739	0.753	0.750	0.747	1.00							
Cu	0.879	0.887	0.883	0.815	0.669	1.00						
Fe	0.914	0.943	0.947	0.888	0.768	0.755	1.00					
Hg	0.885	0.867	0.881	0.807	0.575	0.882	0.760	1.00				
Ni	0.959	0.963	0.958	0.880	0.753	0.874	0.927	0.855	1.00			
Pb	0.809	0.814	0.811	0.824	0.567	0.804	0.739	0.788	0.761	1.00		
Ti	0.954	0.975	0.978	0.914	0.796	0.822	0.982	0.815	0.955	0.759	1.00	
Zn	0.867	0.887	0.881	0.796	0.710	0.887	0.844	0.788	0.885	0.799	0.88	1.00

TABLE 6. PCA of metal elements in soil for dry and rainy seasons

PCs	Dry season			Rainy season		
	Eigenvalue	Variability (%)	Cumulative (%)	Eigenvalue	Variability (%)	Cumulative (%)
F1	18.267	86.987	86.987	18.533	88.253	88.253
F2	1.07	5.118	92.105	0.906	4.3147	92.567
F3	0.416	1.98	94.085	0.398	1.8962	94.464
F4	0.391	1.861	95.946	0.335	1.5943	96.058
F5	0.23	1.095	97.041	0.263	1.2521	97.310
F6	0.162	0.774	97.814	0.180	0.8575	98.168
F7	0.119	0.566	98.38	0.151	0.7183	98.886
F8	0.076	0.362	98.742	0.080	0.3829	99.269
F9	0.058	0.277	99.019	0.055	0.26	99.529
F10	0.051	0.244	99.263	0.043	0.2068	99.736
F11	0.042	0.202	99.465	0.016	0.077	99.813
F12	0.035	0.167	99.633	0.015	0.0734	99.886
F13	0.026	0.122	99.755	0.009	0.0452	99.931
F14	0.016	0.077	99.832	0.007	0.0318	99.963
F15	0.013	0.063	99.895	0.003	0.0165	99.979
F16	0.008	0.036	99.931	0.002	0.0121	99.991
F17	0.004	0.02	99.952	0.001	0.0047	99.996
F18	0.004	0.018	99.97	0.0005	0.0025	99.999
F19	0.003	0.013	99.983	0.0002	0.001	100
F20	0.002	0.01	99.993			
F21	0.001	0.007	100			

TABLE 7. Factor analysis of PC's before and after varimax rotation in dry season

Metal	Before rotation					After rotation	
	F1	F2	F3	F4	F5	D1	D2
Fe	0.96	-0.24	0.02	-0.11	0.01	0.91	0.37
Mn	0.72	0.61	0.29	-0.07	0.00	0.22	0.91
Cr	0.78	-0.28	0.32	0.44	-0.08	0.79	0.24
Cu	0.89	0.28	-0.11	0.25	0.09	0.55	0.75
Pb	0.85	0.40	0.18	-0.14	0.00	0.45	0.82
Zn	0.92	0.09	0.02	0.10	0.35	0.68	0.62

TABLE 8. Factor analysis of PC's before and after varimax rotation in rainy season

Metal	**Before rotation**					**After rotation**
	F1	F2	F3	F4	F5	D1
Fe	0.95	-0.08	0.14	0.09	0.11	0.95
Mn	0.95	-0.04	0.19	0.21	-0.03	0.95
Cr	0.87	0.29	0.19	0.20	-0.25	0.87
Cu	0.92	0.07	-0.22	-0.14	-0.15	0.92
Pb	0.88	0.08	0.33	-0.21	-0.07	0.88
Zn	0.85	-0.29	-0.28	0.23	-0.07	0.85

TABLE 9. Results of cluster analysis for dry season

	Dry season			Rainy season		
Class	1	2	3	1	2	3
Within-class variance	4511.68	18600.6	0	3042.84	12931.7	4559.7
Minimum distance to centroid	24.73	91.24	0	25.54	66.04	41.03
Average distance to centroid	58.81	118.99	0	48.77	99.09	54.26
Maximum distance to centroid	122.52	170.28	0	89.06	148.21	64.25
Metal elements	Fe, Ni, Cd, As, Co, Na, K, Ca, Al,Ti, Sb, Sc, Sr, V, Ba	Mn, Cu, Pb Zn, Hg	Cr	Fe, Cu, Ni, Co, Ca, Al, Ti, Sb, Sc, Sr, V, Ba	Mn, Cr, As, Hg, Na, K	Pb, Zn, Cd

CONCLUSION

Results obtained from normal QQ plot reveal that almost all the metal elements in soil for both the dry and rainy seasons were distributed normally, except As. Conventional statistics depicted that the concentration of metal elements considered in this study showed a great degree of variability due to the generation of metal elements from anthropogenic activities. The level of metal elements exhibited almost same concentration pattern as Fe> Al>K>Ca>Ba>Na>Pb>V> Ti >Sr>Zn> Mn>Sc>Cu>Sb> Co> Cr>Hg>As> Ni>Cd in both the dry and rainy season. Pearson's correlation reveals that all the metal elements were strongly correlated indicating these metal elements were derived from the same generation sources. In dry season, metal elements of Al, As, Ba, Ca, Cd, Co, Fe, K, Na, Ni, Sb, Sc, Sr, Ti and V derived from anthropogenic activities and Cu, Hg, Mn, Pb and Zn in soil were derived from natural parent materials and Cr derived from both the anthropogenic activities and natural parent materials. It was also estimated that As, Cr, Hg, K, Mn and Na in soil were derived from natural parent materials and metal elements of Al, Ba, Ca, Co, Cu, Fe, Ni, Sb, Sc, Sr, Ti and V derived from anthropogenic activities. The generation sources of all studied metal elements in soil obtained from PCA were completely in agreement with AHC for both the dry and rainy seasons.

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Persian Abstract

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چکیده

تمرکز اصلی این مطالعه نشان دادن منابع تولید احتمالی آلودگی فلز در خاک است. تنها دفاتر دفن زباله مجاز در راجبدج واقع در خلنه در بنگلادش. برای این تلاش ها، مجموع ۶۰ نمونه خاک در عمق ۳۰-۳۰ سانتی متر از سطح زمین موجود و عناصر فلزی مربوط به آل، As، Ba، Ca، Cd، Cr، Co، Cu، Fe، Hg، K، Mn، Na، Ni، Pb، Sb، Sc، Sr، Ti، V و Zn از طریق روش های استاندارد در آزمایشگاه اندازه گیری شد. نتایج مورد نظر برای آزمون عادی حاصل از طرح QQ طبیعی با استفاده از XLSTAT. تقریبا تمام عناصر فلزی به طور معمول در هر فصلی توزیع شد. با استفاده از XLSTAT آمارهای چند متغیره مانند همبستگی پیرسون، تجزیه و تحلیل مولفه اصلی (PCA) و خوشه بندی سلسله مراتبی aglomerative (AHC) برای نشان دادن همبستگی میان عناصر فلزی و منابع تولید احتمالی آنها انجام شد. نتایج حاصل از آمار چند متغیره نشان داد که تقریبا تمام عناصر فلزی به شدت وابسته هستند که نشان دهنده منابع مشابه یک نسل است. علاوه بر این، نتایج PCA و AHC نشان داد که تقریبا تمام عناصر فلزی در خاک حاصل فعالیت های انسان / انسان است؛ حداقل تعداد عناصر فلزی از منابع طبیعی و نیز از منابع طبیعی و انسان شناسی. شناسایی مناسب و کنترل منابع تولید احتمالی عناصر فلزی ممکن است سبب کاهش آلودگی خاک به دلیل عناصر فلزی در محل دفن زباله شود.