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Multivariate Statistical Analysis of Trace Elements in Soil of Gazipur Industrial Area, Bangladesh

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Abstract:

The study is mainly focused on assessment of agricultural soil contamination and its degradation scenario by trace elements which are mainly attained from industrial activity and agrochemicals at Gazipur district. Twenty soil samples were collected randomly from different locations of Gazipur along the river side of agricultural fields. Most of the trace elements concentration is higher than world average. There are two main clusters among trace elements. There are significant positive correlations among the elements according to Pearson Correlation Matrix and minimal to moderate enrichment factor indicates anthropogenic sources. The highest geo-accumulation index are contributing extremely pollution scenario of the study area. Contamination factor indicates that the study areas are both moderately to less contaminated by the heavy metals. Pollution load index analyses indicate that the places are polluted by trace elements and their sources are mostly industrial processes and agrochemicals. Principle component 1 denotes mainly natural source of elements. But principle components 2 stands for mainly anthropogenic sources. So, it is evident that the soil in the study area has been degrading severely through trace elements contamination mostly from anthropogenic sources and it has great possibility that plants would uptake heavy metals from the soil.

Keywords: Trace elements, Cluster, Correlation, Geo-accumulation index, Contamination factor, Principle component, Pollution Load Index

1.0 Introduction:

Soil is a crucial environmental component which is a composite mixture of different elements both biotic and a biotic. Soil acts as sink or reservoirs of materials come from different sources both natural (rocks and minerals weathering) and anthropological sources like industrial or agrochemicals. Soil quality depends on the components present in soil matrix but it can be altered by different means. Soil contamination refers to the mixtures of unwanted contaminants or elements into or onto soil, as a result of human derived activity like industrial, agricultural or natural processes, and can have adverse effects on quality of both the environment and human health because plants uptake the contaminants as a nutrient by root and accumulates in the leaves, seed, shoot and finally it goes into the food chain which has significant health impacts of human being and on biota (RPSMSQ 2010). Soil pollution by heavy metals, such as copper, lead, chromium, zinc, nickel, arsenic etc. is a major problem of concern. Although heavy metals are naturally present in soil, but also come, from local sources such as automobile, battery, pharmaceuticals, power plants, iron, steel and chemical industries; agriculture sources such as fertilizer, especially phosphates, contaminated manure and pesticide containing heavy metals; waste incineration, combustion of fossil fuels and road traffic (PEA 1995; Jolly et al. 2013). Gazipur district is highly vulnerable to environmental pollution specially soil pollution due to rapid industrialization and urbanization. Pollution of the environment with trace metals has increased alarmingly in recent years since the onset of the industrial revolution (Nriagu 1979). Industrial activities such as manufacturing and processing industries may lead to the perturbation of the natural ecosystem and as a consequence environmental pollution occurs.

Polluted water consequently contaminates surrounding soil during wet season (PEA 1995; Jolly et al. 2013). The accumulation of heavy metals in agricultural soils disposal, waste incineration, urban effluent, traffic is of increasing concern due to the food safety issues and emissions, fertilizer application and long term application poses great ecological risk and health hazard of the dwellers (Bilos et al. 2001; Koch et al. 2001). Trace metals are accumulated in the body parts of the plants and are consequently transferred into the human body through food chain. In this point of view, it is very significant to carry out a study to determine the present scenario of trace elements (Cr, Co, Cu, Zn, Pb, Hg, Ni, As, Rb, Y, U, Ga, Yb, etc.) in agricultural soil of Gazipur district, Bangladesh.

1.1 Study area:

Gazipur District is lying at just north of capital city of Dhaka, Bangladesh. Gazipur district is situated between 23˚53' to 24˚20' North latitudes and between 90˚09' to 90˚42' east longitude. The total area of the district is 1806.36 sq. km of which 17.53 sq. km is riverine and 273.42 sq.km.is forest area (District Statistics Gazipur 2011). The study area belongs to the 'Madhupur Tract' which is situated at the northern part of Dhaka and is slightly elevated terrace-like topography. The soil is light to medium grey, fine sandy to clayey silt. Soils are poorly stratified and composed by alluvium soil of the Pleistocene period (Khan et al. 2008). Most of the soils are manganese and iron rich as a result oxidized easily and reddish in color.

2.0 Materials and Methods:

Study areas were selected around the Bangladesh Small Cottage and Industrial Corporation (BSCIC), Tongi industrial area, Gazipur because most of the industrial pollution occurred around these areas. Most of the samples locations were selected along the riverside of the study area randomly. All of the samples were collected with following proper procedure for the purpose of WD X-ray fluorescence analysis.

2.1 Sampling Location and Collection Procedure:

Samples were collected randomly and locations were determined by a hand GPS (model no-GPS map 62 GARMIN). The sampling points are shown in Figure a. Total 20 soil samples were collected from different location at Gazipur, Kaliakoir Upazilla during pre-monsoon period which are significantly concern about industrial pollution. Most of the soil samples were collected from the vicinity of the water bodies where effluents were discharged. Samples were collected randomly by traverse method. Three samples were collected from residential areas where the influence of industries was lower than the other locations. Soil samples were collected from the residential areas, industrial areas, agricultural soil from half feet depth by hand augar. Samples were then divided into 8 in number and mixed homogenously. Samples were preserved in polythene bags in order to prepare for analyzing by WDXRF.

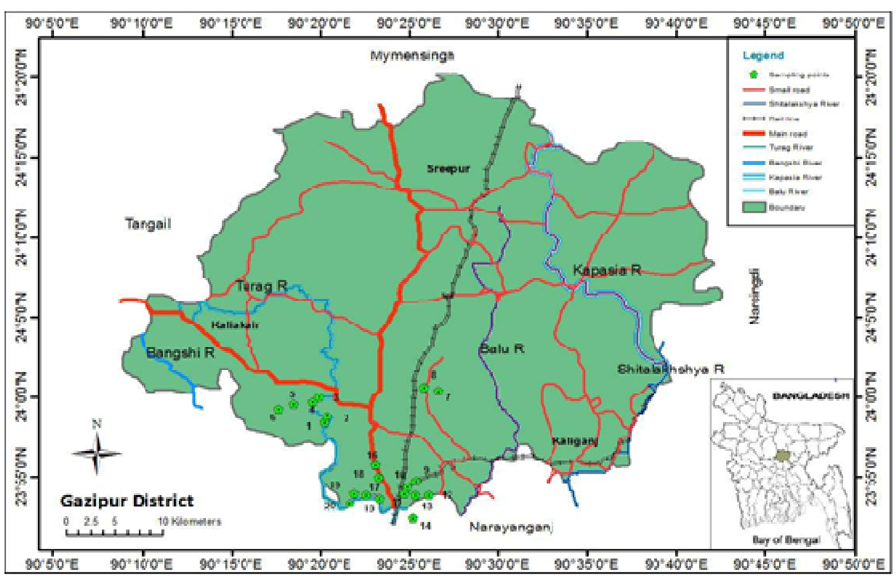
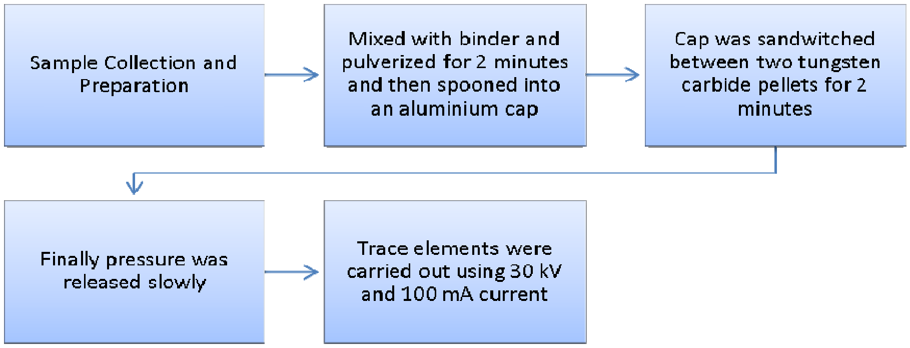


Figure a: Sample Location of the study area



2.2 Elemental Analysis by XRF:

Total concentrations of geochemical variables (trace elements) in soil samples were measured by WDXRF at the Institute of Mining, Mineralogy and Metallurgy; Bangladesh Council of Scientific and Industrial Research (BCSIR), Joypurhat following the procedures outlined by (Qishlaqi and Farid 2007; Goto and Tatsumi 1996**)** through using Rigaku ZSX Primus XRF machine equipped with an end window 4 kW Rh-anode X-ray tube. The samples were mixed with binder (steric acid: sample at a ratio of 1:10) and pulverized for two minutes. The resulting mixture was spooned into an aluminum cap (30 mm). The cap was sandwiched between two tungsten carbide pellets using a manual hydraulic press with 10 tons/sq. in for 2 minutes and finally pressure was released slowly. Measurements of trace elements were carried out using 30 kV voltage and 100 mA current, respectively. The Geological Survey of Japan (GSJ) stream sediments (JSD) series have been used as a standard in the analyses and the precision is found better than ±5% for all analyzed elements (Halim et al. 2011; Faisal et al. 2014; Majumder et al. 2015). Flowchart showing the stages of sample analysis:

2.3 Statistical Analysis:

2.3.1 Cluster Analysis:

Cluster analysis, a multivariate statistical technique, has been widely used to interpret complex data and to identify sources of pollution. Cluster analysis is a statistical technique of grouping a wide range of complex data into few groups having similar characteristics or to identify similar sources (Mihailovic et al. 2014).

2.3.2 Pearson Correlation Matrix:

Pearson correlation coefficient is commonly used to measure and establish the strength of a linear relationship between two variables or two sets of data. It is a simplified statistical tool to show the degree of dependency of one variable to the other (Belkhiri et al. 2010). The Pearson correlation coefficient (r) is computed by using the formula as given (Patil and Patil 2010; Jothivenkatachalam et al. 2010; Kumar and Sinha 2010).

Pearson correlation matrix=

$$\frac{n(\sum xy-(\sum x)(\sum y)}{\sqrt{[n\sum x^2-(\sum x)^2][n\sum y^2-(\sum y)^2]}} \quad .... (1)$$

Where, the variables x and y represents two different soil quality parameters;

n= number of data points/ number of soil samples.

Pearson correlation coefficient has been determined by SPSS 16 software.

2.3.3 Enrichment Factor:

Enrichment factor is used to determine the source of the metals. Enrichment factor (EF) is one of the useful tools to speculate on the origin of elements in the soils whether it is natural or anthropogenic (Loska et al. 1997).

It was calculated using the following relation (Yaqin et al. 2008):

$$EF = ([M]/[Fe])Sample/([M]/[Fe])Background \quad ....(2)$$

Where ([M]/[Fe])Sample is the ratio of the concentration of test element (M) to that of Fe in the sample and ([M]/[Fe])Background is the same ratio in reference soils of the study area. Iron (Fe) was used as the reference element for geochemical normalization because Fe is associated with fine solid surfaces, its geochemistry is similar to that of many trace metals and its natural concentration tends to be uniform (Daskalakis and OConnor 1995). The EF values close to unity indicate crusted origin, those less than 1.0 suggest a possible mobilization or depletion of metals (Zsefer et al. 1996), whereas EF >1.0 indicates that the element is of anthropogenic origin.

2.3.4 Geo-Accumulation Index:

The evaluation of anthropogenic influence and contamination with trace elements in soil of study area was carried out using geo accumulation index. I_{geo} values which permit the assessment of degree of soil contamination with respect to global standards.

$I\text{-}_{geo}$ is calculated from (Muller 1969; Ji and Feng 2008) using following mathematical equations:

$$I_{geo} = \log 2 \ (Cn / 1.5 \times Bn) \qquad \text{.... (3)}$$

Where, Cn is mean measured total concentration of the examined element 'n' in the studied soil, Bn is average (crustal) geochemical surrounding value for concentration of the element 'n' in basalts (average basalts) and 1.5 is the factor compensate the surrounding data (correction factor) due to lithogenic effect (Taylor 1964).

According to Muller (Muller 1969) the I_{geo} for each trace element is calculated and classified as uncontaminated ($I_{geo} \le 0$), uncontaminated to moderately contaminated ($0 < I_{geo} \le 1$), moderately contaminated ($1 < I_{geo} \le 2$), moderately to heavily contaminated ($2 < I_{geo} \le 3$), heavily contaminated ($3 < I_{geo} \le 4$), heavily to extremely contaminated ($4 < I_{geo} \le 5$), extremely contaminated ($I_{geo} \ge 5$).

2.3.5 Contamination Factor and Degree of Contamination:

The assessment of soil contamination was also carried out using the contamination factor (C_f^i) and degree of contamination (C_d). The C_f^i is the single element index, the sum of contamination factors for all elements examined represents the C_d of the environment and all four classes are recognized (Hakanson 1980). In the version suggested by (Hakanson 1980), they enable an assessment of soil contamination through the reference of the concentration in the surface layer of bottom sediments to preindustrial levels (average shale).

$$C_f^i = \frac{C_c^i}{C_n^i} \qquad \text{......(4)}$$

Where $Ci_{0\text{-}1}$ is the mean content of metals from at least five sampling sites and Ci n is the pre-industrial concentration of individual metal. In the present study, we applied a modification of the factor as applied by (Krzysztof et al. 2003) that used the concentration of elements in the earth's crust as a reference value, similar to the other factors.

2.3.6 Pollution Load Index (PLI):

The Pollution Load Index (PLI) is obtained as concentration Factors (CF). The PLI of the study area are calculated by obtaining the n-root from the n- CFs that was obtained for all the metals. The PLI value of > 1 is polluted, whereas <1 indicates no pollution (Harikumar et al. 2009). Generally Pollution Load Index (PLI) was developed by (Tomlinson et al. 1980), which is as follows:

$$PLI = \text{nth} \sqrt{CF1 \times CF2 \ldots \times CFn}, \qquad \text{.........(5)}$$

2.3.7 Principle Component Analysis:

There are several useful techniques to reduce the dimensionality of data without the loss of much information. Principal component analysis is one such technique. Typically, principal component analysis is used to reduce the dimensionality of a data set, while retaining as much of the original information as possible. This is achieved by transforming the original set of variables into a smaller set of linear combinations called principal components (Jolliffe 1986; Rencher 1995). The components are uncorrelated and account for the total variance of the original variables. The first principal component (PC1) has the largest variance and accounts the greatest amount of the total variance. The second principal component (PC2) has the second largest variance and contributes the greatest amount of the residual variance, and so on. The scree plot is used for examining the classification of the data. The loading plot is used for investigating the importance of variable to each component (Panishkan et al. 2010). PCA has been analyzed by SPSS 16.

3.0 Results and Discussion:

Statistical analysis show the description of the data produced during the analysis. Descriptive statistics are used to describe the basic features of the data in a study (Table 1). They provide simple summaries about the sample and the measures. Means and standard deviation used to describe central maximum values. It is clear from the statistical table that most of the elements showing higher values than world average. Cr, Co, Ni, Zn, Zr, Ga, As, Rb, Y, Sc exhibit several times higher values than world average.

Table 1 Statistical analysis result of trace elements with maximum, minimum and average value in ppm

Sample No.	Cr	Co	Ni	Cu	Zn	Ga	As	Rb	Sr	Y	Zr	Ba	V	Hf	Sc	Th	Pb	Yb	U
S-1	690	24.3	146.64	92	134.4	ND	ND	196.8	241.6	153.66	173.33	856.18	92.43	2.99	26.75	2.47	ND	ND	1.27
S-2	2898	12.31	187	101	169	37.97	36.36	169.83	227.94	96.13	195.33	455.21	94.76	2.94	22.08	2.97	1.6	0.07	1.31
S-3	2875	14.49	173.16	85.6	105.6	ND	28.5	16.38	192.8	102.18	178.13	686.19	99.65	3.05	22.38	3.18	2.49	0.33	1.36
S-4	3698	15.07	168.48	108.8	156.8	40.7	ND	208.39	214.4	90.48	185.00	500.18	189.42	3.04	24.89	3.57	5.26	0.4	1.38
S-5	1481	ND	108.42	72	102.4	ND	ND	16.38	203.2	127.14	310.00	593.63	92.7	3.21	18.37	4.41	8.19	0.73	1.42
S-6	2057	19.34	145.86	98.4	106.4	38.48	ND	252.98	76.8	178.62	328.75	692.42	145.5	3.33	31.3	6.08	15.05	1.17	1.44
S-7	477	9.18	152.88	115.2	109.6	48.1	ND	277.55	68.8	184.86	166.88	711.11	113.89	3.16	23.87	7.3	7.5	0.79	1.31
S-8	713	12.8	141.96	98.4	148	55.5	32.25	235.8	124.8	168.48	257.50	850.84	111.56	3.08	28.74	4.21	6.78	0.54	1.34
S-9	594	15.7	128.37	81.28	120.96	ND	ND	207.85	87.68	9.7344	107.50	589.32	109.94	3.14	28.74	4.03	68.72	0.36	1.35
S-10	1125	46.8	114.66	82.4	204	ND	30.75	172.8	118.4	27.3	250.00	573.6	97.03	3.19	25.95	5.35	9.89	0.88	1.35
S-11	2662	13.52	136.5	80.8	178.4	ND	ND	193.5	133.6	124.8	517.33	551.8	102.67	3.28	24.24	5.56	90	0.96	1.39
S-12	922	10.93	18.84	86.4	121.6	ND	32.25	212.94	109.6	118.56	202.00	574.94	95.15	3.02	33.82	3.24	ND	0.32	1.3
S-13	1250	12.59	137.28	94.4	132.8	46.62	33	216.58	114.4	153.66	160.67	555.36	116.17	3.05	24.27	4.52	3.52	0.33	1.23
S-14	809	10.07	103.74	63.2	77.6	ND	27.75	176.54	59.2	113.1	313.33	394.9	235.62	3.26	26.67	4.67	11.34	0.87	1.44
S-15	1537	10.83	100.62	69.6	111.2	ND	36	163.8	76	85.8	426.00	516.2	96.36	3.26	17.19	5.02	12.81	0.97	1.39
S-16	710	9.68	133.38	42.4	72	ND	ND	170.17	53.6	106.86	448.00	540.23	152.46	3.41	14.85	5.99	16.24	1.12	1.47
S-17	2090	6.69	115.44	51.2	82.4	ND	26.25	169.26	60.8	112.32	402.00	721.79	71.29	3.36	26.83	5.35	12.54	1.13	1.44
S-18	1368	12.44	100.62	44	84	ND	ND	191.1	56.8	117.78	580.67	496.62	91.35	3.35	23.22	5.48	14.26	1.16	1.45
S-19	1915	9.6	138.06	47.2	84.8	ND	ND	162.89	74.4	117.78	308.67	585.62	76.14	3.33	22.46	6.04	15.06	1.22	1.45
S-20	1264	14.54	117	88.8	186.4	36.26	30	182	121.6	115.44	240.00	502.85	106.62	3.42	33.26	6.3	17.18	1.35	1.49
Avg. value	1556.75	14.78	128.45	80.15	124.42	43.38	31.31	179.68	120.82	115.23	287.55	597.45	114.54	3.19	26.03	6.54	17.69	0.77	1.38
World Avg	59.5	11.3	29	38.9	70	15.2	6.83	68	175	23	267	460	129	6.4	11.7	9.2	27	2.6	3
Min. value	477	6.69	18.84	42.4	72	36.26	26.25	16.38	53.6	9.7344	107.5	394.9	71.29	2.94	14.85	2.47	1.6	0.07	1.23
Max. value	3698	46.8	187	115.2	204	55.5	36.36	277.55	241.6	184.86	580.67	856.18	235.62	3.42	42.45	6.54	90	1.35	1.49
SD	907.55	8.698	35.369	21.47	38.61	6.96	3.33	63.67	62.01	43.45	129.59	121.67	39.32	0.15	6.33	8.49	28.79	0.38	0.072
CV	0.58	0.59	0.28	0.27	0.31	0.16	0.11	0.35	0.51	0.38	0.45	0.20	0.34	0.05	0.24	1.30	1.18	0.50	0.05

Table 2: Pearson Correlation of trace elements

	Cr	Co	Ni	Cu	Zn	Ga	As	Rb	Sr	Y	Zr	Ba	V	Hf	Sc	Th	Pb	Yb	U
Cr	1.0																		
Co	-.38	1.0																	
Ni	**.83**	-.77	1.0																
Cu	.48	**.89**	**.89**	1.0															
Zn	.34	.68	-.05	-.35	1.0														
Ga	-.65	-.42	-.12	.35	-.75	1.0													
As	**.80**	-.85	**.98**	**.87**	-.22	-.08	1.0												
Rb	-.81	-.23	-.37	.08	**.76**	**.96**	-.31	1.0											
Sr	**.94**	-.47	**.93**	**.68**	.32	-.44	**.86**	-.67	1.0										
Y	-.85	-.17	-.45	-.01	-.76	**.92**	-.37	**.99**	-.74	1.0									
Zr	-.43	.50	-.32	-.13	.47	.23	-.50	.19	-.19	.15	1.0								
Ba	-.72	-.15	-.24	.22	-.45	**.93**	-.28	**.89**	-.46	**.84**	.58	1.0							
V	-.88	.11	-.72	-.42	-.65	.63	-.59	**.82**	-.93	**.86**	-.06	.52	1.0						
Hf	-.47	**.99**	-.83	-.92	.59	-.34	-.90	-.14	-.57	-.07	.48	-.09	.22	1.0					
Sc	-.72	**.83**	-.80	-.65	.40	.13	-.91	.26	-.65	.29	**.82**	.43	.34	**.85**	1.0				
Th	-.60	**.93**	-.94	-.97	.38	-.22	-.95	.03	-.76	.11	.34	-.04	.45	**.97**	**.81**	1.0			
Pb	-.45	**.99**	-.79	-.86	.65	-.31	-.88	-.18	-.51	-.08	.59	-.03	.15	**.99**	**.89**	**.93**	1.0		
Yb	-.51	**.99**	-.84	-.86	.59	-.27	-.92	-.08	-.58	-.02	.57		.22	**.99**	**.90**	**.95**	**.99**	1.0	
U	-.16	**.90**	-.48	-.61	**.87**	-.44	-.64	-.37	-.15	-.35	.72	-.09	-.23	**.86**	**.80**	**.70**	**.91**	**.88**	1.0

Table 3: Enrichment Factor, Geoacculation Index, and Contamination Factor of Trace Elements

Sample No		**Cr**	**Co**	**Ni**	**Cu**	**Zn**	**Ga**	**As**	**Rb**	**Sr**	**Y**	**Zr**	**Ba**	**V**	**Hf**	**Sc**	**Th**	**Pb**	**Yb**	**U**
EF	Avg	2.54	1.3	0.87	0.89	1.09	0.26	0.5	0.78	1.36	0.7	1.02	0.83	0.89	0.98	0.9	1.3	0.4	0.99	0.99
	Min	0.77	0.8	0.13	0.6	0.74	0.57	0.7	0.06	0.71	0.1	0.32	0.53	0.58	0.7	0.5	0.4	0.03	0.1	0.7
	Max	5.05	4.3	1.26	1.3	1.83	0.95	1.3	1.17	2.33	1.2	2.34	1.3	2.1	1.4	1.4	7.98	1.7	1.95	1.4
GI	Avg	19	6.5	13.5	12.1	13.1	10.5	9.4	14.5	12.5	13.3	15.6	18.1	13.2	7.1	8.9	4.1	8.77	-1.5	0.42
	Min	17.5	5.6	10.8	11.24	12.36	10.29	9.14	11.28	11.52	9.96	14.35	17.49	12.55	6.57	8.18	3.07	5.73	-4.71	0.17
	Max	20.5	8.4	14.1	12.9	13.8	10.9	9.6	15.4	13.7	14.2	16.8	18.6	14.3	7.2	9.7	7.2	11.6	-0.4	2.2
CF	Avg	1.61	1.4	0.88	0.87	1.1	0.78	0.97	0.75	1.42	0.8	0.99	0.85	0.91	0.99	0.9	1.3	0.4	0.98	0.9
	min	0.49	0.6	0.13	0.5	0.66	0.67	0.8	0.07	0.51	0.1	0.37	0.56	0.57	0.9	0.5	0.5	0	0.1	0.9
	max	3.83	4.4	1.31	1.28	1.86	0.93	1.1	1.11	2.93	1.2	2	1.22	1.87	1.1	1.4	8.3	1.8	1.7	1.1

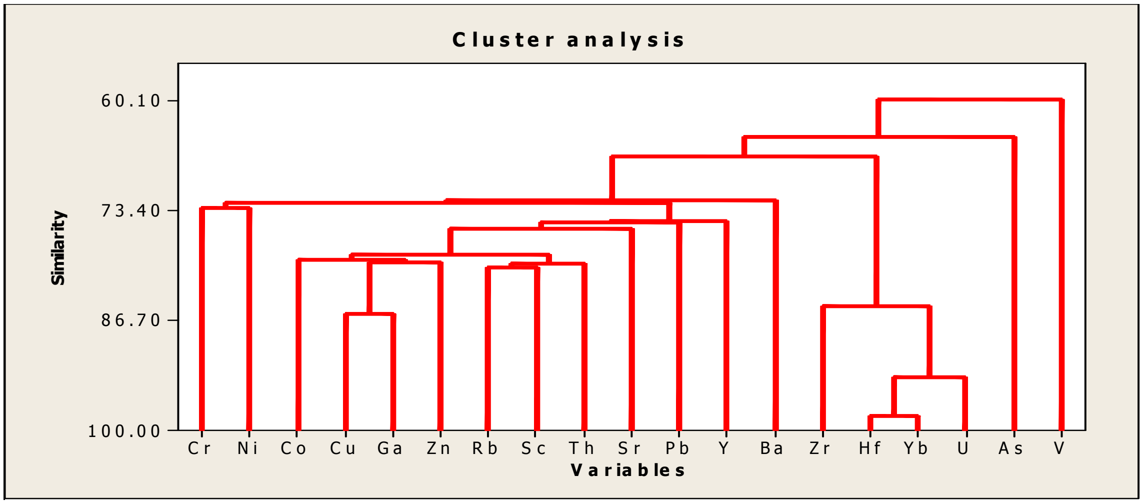


Figure b: Cluster Analysis for Trace Elements

Table 4: Degree of contamination and Pollution Load Index for Trace Elements

Sample No	Degree of Contamination (Cd)	Pollution Load Index(PLI)
S-1	17.03	0.88
S-2	19.91	0.85
S-3	17.73	0.60
S-4	21.38	1.03
S-5	15.20	0.81
S-6	19.94	1.68
S-7	13.16	0.89
S-8	13.84	0.88
S-9	15.36	0.78
S-10	20.28	0.92
S-11	20.37	1.14
S-12	14.62	0.81
S-13	17.99	0.87
S-14	15.87	1.14
S-15	16.66	0.89
S-16	15.91	0.96
S-17	16.69	0.86
S-18	16.05	0.89
S-19	16.06	0.91
S-20	19.80	0.99

3.1 Cluster Analysis of Trace Elements:

Cluster analysis is showing a number of small clusters unit which are belonging under two major cluster groups and those cluster is differing significantly from each other. Cluster 1 involves variables Cr- Ni, Co- Cu-Ga-Zn, Rb- Sc- Th, Sr – Pb-Y-Ba. Cluster 2 includes variables Zr- Hf-Yb-U-As-V. Cr and Ni are extensively used in different alloy industries and other types of industries. Co, Cu, Ga, Zn are may be used in soil as fertilizer or for industrial purposes. Rb, Sc are used in glass industries. Sr, Pb, Y, Ba come from both natural and industrial sources. Cluster 2 elements mostly may come from natural sources but anthropogenic sources may also involve. Hierarchical Cluster Analysis of Trace Elements is shown in Figure b.

3.2 Pearson Correlation of Trace Elements:

Pearson correlation coefficients among trace elements show wide range of variety. There are strong positive to strong negative relation among elements. Ni has strong positive correlation with Cr (r=.83) which may came from common source for instance alloy industries which use Cr, Ni extensively. Cu has strong positive correlation with Ni and Co (r= .89 and r=.89) which are used in fertilizer and alloy industries. As has strong correlation with Cr, Ni, Cu, which means their source may be common from agrochemicals or industrial use. Rb has strong positive correlation with Ga and Zn (r=.96 r= .76) which may come from the same minerals or. Sr showed strong positive correlation with Cr, Ni, As (r= .94, .93 and .86) which may from the same type of industry such as alloy, pigment industries or minerals. Y has moderate positive correlation with Ga and Rb (r= .92 and 99) mainly originate from common minerals and Ba showed strong correlation with Ga, Rb and Y may from common geological materials (r=.93, .89 and .84) or may used in industries. V showed strong positive correlation with Rb, Y (r=.82 and .86) indicate geological sources. Pb has positive relation with Co, Hf, Sc, Th, Yb and U (r= .99, .99, .89, .93,. 99 and .91) which means common type of pollution sources from industries and geological sources. Yb has Strong positive correlation with Co, Hf, Sc, Th, Pb and U (r= .99, .99, .90, .95, .99, .88) indicates mixed sources like geological and industrial. U showed strong positive correlation with Co, Hf, Sc, Th, Pb, Yb (r= .90, .86, .80, .70, .91, .88)) may come from geological source.

3.3 Enrichment Factor of Trace Elements:

Enrichment Factor of trace elements reveals that Cr showed moderate enrichment factor 2.54 which ranges from 0.77 to 5.05, Co from 0.80 to 4.31, Ni from 0.13 to 1.26, Cu from 0.60 to 1.30, Zn from 0.74 to 1.83, Ga from 0.57 to 0.95, As from 0.70 to 1.33, Rb from 0.06 to 1.17, Sr from 0.71 to 2.33, Y from 0.06 to 1.16, Zr from 0.32 to 2.34, Ba from 0.53 to 1.30, V from 0.58 to 2.10, Hf from 0.74 to 1.35, Sc from 0.53 to 1.39, Th from 0.38 to 7.98, Pb 0.03 to 1.67, Yb from 0.07 to 1.95 and U from 0.73 to 1.37. From the observation it can be concluded that the elements show minimal to moderate enrichment factor. Co, Ni, Zn, Sr, Zr show minimal enrichment factor which background values are higher than the world average. There are no industry surrounding the areas but may be deposited the metals during wet season when river water flooded the area. Enrichment Factor of trace elements is shown in Table 3.

3.4 Geoaccumulation Index of Trace Elements:

The I_{geo} values(Table 3) for the heavy metals of environmental significance ranging from (17.53 - 20.48) for Cr, (5.56-8.36) for Co, (10.81-14.12)for Ni, (11.24- 12.68)for Cu, (12.36 -13.87) for Zn, (10.29-10.90) for Ga, (9.14-9.61) for As, (11.28-15.36)for Rb, (11.52- 13.70) for Sr and (9.96- 14.21) for Y. Highest geoaccumulation index showed Cr,Co, Ni, Cu, Zn, Ga, As, Rb, Sr, Y, Zr, Ba, V, Hf, Pb, Sc which are extremely contaminated. Source of these elements are mostly anthropogenic which are used in different industries, agrochemicals residue for plant growth. Lower geoaccumulation index were shown by Yb, U, Th which means uncontaminated by these elements.

3.5 Contamination Factor for Trace Elements:

From the assessment it can be concluded that Contamination Factor (Table 3) shows a great variety for different trace elements. Most elements show moderate degree of contamination. The range for Cr is (0.49- 3.83), (0.63-4.43) for Co, (0.13- 1.31)for Ni, (0.50- 1.28) for Cu, (0.66- 1.86) for Zn, (0.67- .93) for Ga, (0.81- 1.13) for As, (0.07- 1.11) for Rb, (0.51-2.93) for Sr, (0.06- 1.16) for Y, (0.37- 2.00) for Zr, (0.56- 1.22) for Ba, (0.57- 1.87) for V, (0.91- 1.06) for Hf, (0.45- 1.15) for Sc, (0.29- 1.24) for Th, (0.03-1.81) for Pb, (0.09- 1.65) for Yb and (0.90- 1.08) for U. Moderate degree of contamination explicit by Cr, Co, Zn, Sr, Th which contamination factor ranges from 1-3. Most of these elements are used in industrial processes. Low degree of contamination showed by Ni, Cu, Ga, As, Rb, Y, Zr, Ba, V, Hf, Sc, Pb, Yb and U exhibit CF lower than 1 which indicates lower anthropogenic source.

3.6 Degree of Contamination for Trace Elements:

From the overall analysis it can be supposed that highest degree of contamination for trace elements are present in sample-10 (20.28) and sample 11 (20.38). All of the samples are mostly contaminated by the trace elements which range from 13.16 - 20.37. Most locations are occupied by different industries which use different types of chemicals which contain trace elements such as cobalt (Co), copper (Cu), chromium (Cr), nickel (Ni), lead (Pb), barium (Ba), zinc (Zn) that are required for various process industries (WHO 1996). Degrees of contamination for trace elements are shown in Table 4.

3.7 Pollution Load Index for Trace Elements:

Calculated Pollution Load Index for trace elements showed in Table -4 that most of the elements PLI are very close to the 1 which mean pollution of the area. Utmost PLI has been observed in sample 4, 6, 11, 14, which is higher than 1. Rests of the samples are very close to pollution.

3.8 Principle Component Analysis of Trace Elements:

Principle Component Analysis reveals the main elements which are needed for formation of soil matrix. PC1 involves Yb, Th, Hf, Pb, Sc, Co, U, Y, V, Ba which means soil can't be constituted without these elements. PC2 and PC3 denotes the elements involve Co, Cu, As, Pb, Ni, Sr, Cr, Rb, Y, Ga, Zn, Zr mainly from anthropogenic sources such as industrial sources and agrochemicals. PC1 denotes 55% variance; PC2 denotes 34.41% variance and PC3 denotes 10.63% variance. PCA and total variance of trace elements is shown in Table 5.

3.9 Scree Plot of Trace Elements:

Scree plot is the graphical representation of the Principle Components. It represents the components which required completing total variance of soil arrangement. From the graph it is clear that trace elements required 3 Principle Components for 100% variance. Scree plot of trace elements is shown in figure c.

Table 5: Component Matrix

Elements	Component		
	PC1	PC2	PC3
As	-.989	-.132	.345
Yb	.963	-.269	-.247
Th	.961	-.126	
Hf	.947	-.313	
Pb	.942	-.329	.259
Ni	-.938	-.230	.350
Sc	.935		
Co	.913	-.407	.443
Cu	-.874	.201	.285
Sr	-.767	-.574	.360
U	.748	-.558	
Cr	-.722	-.692	.610
Rb	.187	.976	
Y	.246	.969	.306
Ga		.952	.315
Zn	-.360	-.878	.557
Ba	.210	.803	-.389
V	.468	.794	-.824
Zr	-.567		.677

Total Variance Explained

Component	Total	Initial Eigenvalues % of Variance	Cumulative %
1	10.442	54.958	54.958
2	6.538	34.411	89.368
3	2.020	10.632	100.000

Figure c: Selected photos of study area showing the industrial pollution scenario

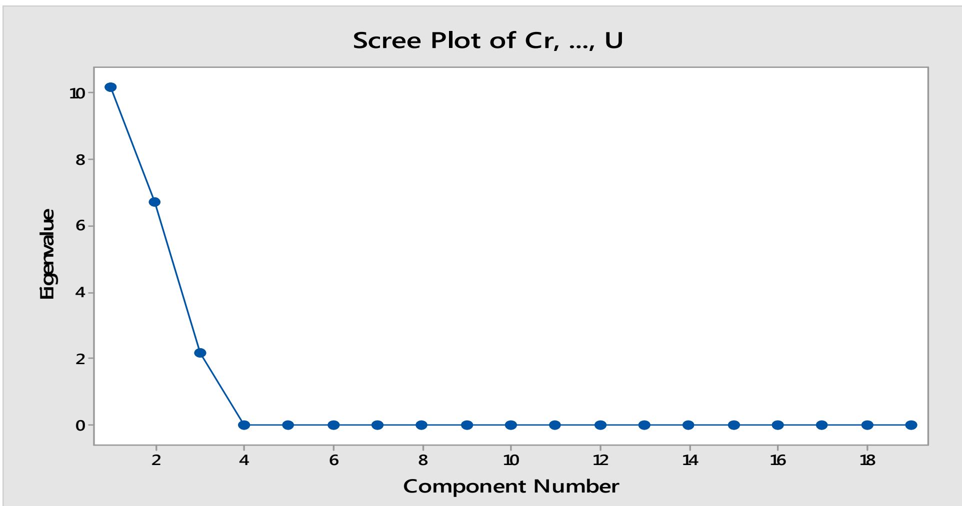


Figure d: Scree plot of trace elements

4.0 Conclusions:

The present scenario of the soil status at Gazipur district is determined and shows present trend of pollution phenomena due to unplanned industrial expansion. Cluster analysis reveals that there are two main clusters among trace elements. Minimal to moderate enrichment factor is indicating anthropogenic sources of the elements. From the geo-accumulation study, the highest geo-accumulation index of Cr, Co, Ni, Cu, Zn, Ga, As, Rb, Sr, Y, Zr, Ba, V, Hf, Pb, Sc are contributing extremely contaminated scenario of the study area but on the other hand lower geo-accumulation index of Yb, U, Th are less responsible to contamination. From this point of view it can be concluded that the study area is moderate to extremely polluted. According to contamination factor the study areas is moderately contaminated by Cr, Co, Zn, Sr, Th,; and less contaminated by Ni, Cu, Ga, As, Rb, Y, Zr, Ba, V, Hf, Sc, Pb, Yb, U. The degree of contamination analyses shows that the study area is moderate to considerable degree of contamination by trace elements and their values are ranging from 13.16 to 20.37, respectively. The Pollution load index (PLI) analyses indicate that most of the places of the study area are polluted by major elements and their sources may be industrial processes and agrochemicals. The Principle component analysis shows that there are three PC for trace elements. From this study, the principle component 1 denotes mainly natural source of elements but principle components 2 and 3 stand for natural or anthropogenic sources. It can be concluded from present study that the soil of the study areas soil has been degrading severely through trace elements contamination mostly from anthropogenic sources and it has possibility that plants could uptake heavy metals from the soil as a nutrient by root and thus accumulate in the leaves, seed, shoot.

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