Assessment of The Heavy Metal Pollution in The Sediment Samples of Major Canals in Dhaka City by Multivariate Statistical Analysis

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Abstract

In this study, the levels of selected metals (Cd, Cr, Cu, Mn, Fe and Pb) concentrations were measured by Flame Emission Atomic Absorption Spectrophotometer (FL-AAS) in sediment (sludge) samples collected from 10 different Canals in and around the Dhaka City Corporation (DCC) area of Bangladesh. The analysis result shows that Cr, Cu and Pb were present as major pollutants in the some canals in the DCC area with high concentration levels, while Cd, Mn and Fe emerged as minor pollutants. Principal Component Analysis (PCA) and Cluster analysis were used to assess the metal contamination in the canals. Positive correlations were found between Mnâ??"Fe (r = 0.860), Pbâ??"Cu (r = 0.786), Pbâ??"Cd (r = 0.398) and Cu-Cd (r = 0.227) pairs. The present metal concentration in the canal sediments data shows that Cr, Pb and Pb levels are higher than recommended sediment quality guideline by USEPA but pollutants concentrations in the sludge are below the prescribed hazard limit provided by USEPA for land application of sludge.

Index terms— Canals, sludge, heavy metal, Principal component analysis, Cluster analysis

1 Introduction

n the current decades the heavy metal accumulation in the soils is a growing concern due to its potential health risks as well as its detrimental effects on soil ecosystems (McLaughlin et al., 1999;Qishlaqi & Moore, 2007). Heavy metals have characteristics including that they are non-biodegradable (Facchinelli et al. 2001) and they can be necessary or beneficial to plants at certain levels, but can be toxic when exceeding specific thresholds (Qishlaqi & Moore, 2007;Bilos et al., 2001) Sources of these elements in soils mainly include natural occurrence derived from parent materials and anthropogenic activities. Anthropogenic inputs are associated with industrialization and agricultural activates, deposition, such as atmospheric deposition, waste disposal, waste incineration, emissions from traffic, fertilizer application and long-term application of wastewater in agricultural land (Qishlaqi & Moore, 2007;Bilos et al., 2001; **??**cLaughlin et al., 2001;Koch et al., 2001).

For the present day's environmental researchers, knowledge of the heavy metal accumulation in soil, the potential source of heavy metals and their possible interactions with soil are one of the prime focuses. Different statistical analysis tools can provide such knowledge and can be very helpful for the interpretation of environmental data (Tuncer et al., 1993;Sena et al., 2002;Einax et. al 1999). In recent times, the statistical methods (univariate or multivariate) have been applied widely to investigate heavy metal concentration, accumulation and distribution in soils. (Vega et al. 1998;Wunderlin et al., 2001;Grande et al., 2003;Simeonov et al., 2003;Pekey et al., 2004;Singh et al., 2004;Astel et al., 2006;Kowalkowski et al., 2006;Shrestha & Kazama, 2007Salman et al., 1999).

Once, Dhaka City, the capital of Bangladesh had excellent natural drainage system even 40 years ago. The city was interlaced with numerous natural channels/canals and wetlands. It is estimated that there were up to

45 natural drainage canals that span the city. In the course of rapid expansion of the city, most of the natural drainage canals as well as wetlands has been intervened and destroyed. Now only few canals exist but these have become contaminated wetland because of disposal of solid waste, toxic industrial waste which are the potential sources of heavy metal pollution (Subramanian, 2004;Karn & Harada, 2001). Now even after a medium size rainfall, the streets of the city get flooded for hours at a time because water has no way to drain out easily. Although some drainage structures have been built over the last two decades, they are woefully inadequate. In addition, due to haphazard design and construction of these drainage structures and lack of proper maintenance, over the years these have lost their carrying capacity due to severe clogging. The effects of water logging causes serious suffering of the city dwellers as well as damage the roads and thereby increasing the road maintenance cost. On the other hand, water supply and sanitation infrastructures have been being become ineffective due to unwanted water logging in the city. There is thus an immediate need for rehabilitation and development of the natural I drainage network and find ways to properly operate and maintain the already constructed drainage structures, such as box culverts and drain lines. For the restoration of these canals in Dhaka city, it is very important to explore the current pollution status of the sludge deposited at the bottom of canals over the year. The present study stems from the above concerns, with the primary focus on the current status of distribution of some selected toxic metals in the sludge sample collected from 10 major canals in the Dhaka city Corporation (DCC) area by multivariate statistical analysis.

2 II. Major Canals in Dcc Area and Their Present Conditions

The major canals (Khals) are located in the various part of the city and their other particulars are shown in the Table 1. From our field survey, it was found that illegal encroachment and nearby pollution activities are the major concerns to maintain the natural conditions in most of the canals in Dhaka city. A variety of small industries are building up near the bank of the canals. Various Residential plots are now under construction on the different parts of the canals. The water of the canals water gets polluted and become blackish with lots of waste including construction debris, vegetations, chemical waste, polythene sheets and as a result there is partial drainage blocking. Some photographs, which were taken during our field survey, are presented in Fig. 1

3 Materials and Methods

For the present study, sediment (sludge) samples were collected from 10 canals (name of the canal mentioned in Table 2) on the months of March and April, 2011 and samples were analyzed for the metals, Cd, Cr, Cu, Mn, Fe and Pb. Above mentioned metals concentration in the collected sludge samples were determined by total extraction with Aqua-Regia. Shimadzu, Japan, AA6800). Standard QA/QC protocol was followed throughout, including replicate analysis (1 in every 5 samples), checking of method blanks (1 in every 10 analysis) and standards (1 in every 10 analysis). The estimated metal levels were compared with the permissible safe levels for the sediment sample proposed by USEPA. Multivariate statistical techniques **??**Lin et **??**976) were adopted to assess the metal contamination in the sludge. For this purpose, the well founded techniques of Pearson correlation analysis, Principal Component Analysis (PCA), and Cluster Analysis (CA) were jointly used, the first affording a direct measure of interdependence of the set of variables under investigation while the latter two provides the visual grouping of the data to help understand the interrelated metal clusters produced (Hopke 1992). SPSS software (Version 16.0) was used to perform the multivariate statistical analyses.

IV.

4 Results and Discussion

The Sludge samples analysis results for different heavy metals are presented in Table 2. The comparison between the metals concentration present in the sludge samples of DCC canals with permissible metal concentration limit proposed by USEPA for the sediment sample shows that some canals in DCC area are facing heavy metal pollution.

5 Note: BDL-Below Detection Limit

According to USEPA guideline, the sludge samples of Mohakhali Khal, Mirpur Housing Khal, Segunbagicha Khal, Jirani Khal are heavily polluted with Cu. Baunia Khal, Kalyanpur Shakha 'Gha" (Shewrapara), Segunbagicha Khal, Jirani Khal are heavily polluted with Cr. Pollution level of Pb in Mirpur Housing Khal is also exceed the USEPA heavily polluted criteria. Pollution level of Hazaribagh Khal, Kalyanpur "Kha" Khal , Kalyanpur main Khal ,Digun Khal are comparatively low for all tested heavy metals except Cr. By reviewing the pollutant limits of USEPA against the result from sludge samples analysis, it can be easily stated the pollutants concentration in the sludge of the selected canals are below the prescribed hazard limit for land application but some canals exceed the EPA guideline for heavily polluted sediments for some metal.

Before forming a judgment on the observed distribution of metal levels and interrelationship among them, the metal data was first examined on the basis of linear correlation between metal pairs in terms of significant positive correlation coefficient. Strong positive correlations were observed for Mn -Fe (r = 0.860), Pb -Cu (r = 0.786), Pb -Cd (r = 0.398) and Cu -Cd (r = 0.227) pairs (Correlation matrix is shown in Table 3), indicating the existence of a common source/origin of these metals in the sludge sample. Further confirmation of this hypothesis of 'different heavy metals may have common origin' was secured through multivariate methods of statistical analysis (Hair et al. 1988). In this study, two multivariate techniques were applied: Principal Component Analysis (PCA) and Cluster Analysis (CA). The PCA has emerged as a useful tool for better understanding the relationships among the variables (e.g., metal concentrations in this study) and for revealing groups (or clusters) that are mutually correlated within a data body (Qishlaqi & Moore, 2007). This procedure reduces overall dimensionality of the linearly correlated data by using a smaller number of new independent variables, called principal components (PC), each of which is a linear combination of originally correlated variables. On the other hand, Cluster Analysis (CA) exclusively classifies a set of observations into two or more unknown groups based on combination of internal variables. Therefore, the purpose of CA is to discover a system of organized observations where a number of groups/variables share properties in common, and it is cognitively easier to predict mutual properties based on an overall group membership (Everitt 1993;Jolliffe 1986). This helps define source profiles of variables, such as metal concentrations, and their interpretation in terms of possible sources (Jobson 1991).

Principal Component Analysis (PCA) using Varimax normalized rotation was conducted for common source identification. The variables are correlated with two principal components in which 70.3% of the total variance in the data was found. The rotated Principal Component Loadings are given in Table 4. Principle component plot in a rotated space is shown in Fig. **??**. The first component with 40.92% of variance comprises Pb, Cu (bold figures in Table 4) with high loadings. This association strongly suggests that these variables have a strong interrelationship. The second component (PC2) contributes Mn and Fe at 29.40 % variance, which also infers the strong correlation between this metal pair. The corresponding cluster analysis Dendrogram is shown in Fig. **??**. From the cluster analysis result it can be said that there is a strong correlation between Fe-Mn metal pair, which is a good agreement with PC2, but cluster analysis results did not show a good agreement between Cu-Pb pair. This result suggests that the strong relationship between Cu-Pb pair does not confirm.

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Figure 1: Fig. 1 :

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Figure 2: Fig. 2 :Fig. 3 :

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Serial No.	Canal's Name	Location	Length (Km)
1	Kalyanpur main khal	Western part of the city	3
2	Kalyanpur branch khal -Ka	Western part of the city	1.5
3	Kalyanpur branch khal -Kha	Western part of the city	2.4
4	Kalyanpur branch khal -Gha	Western part of the city	1.56
5	Kalyanpur branch Khal -Umo	Western part of the city	1.78
6	Kalyanpur branch Khal -Cha	Western part of the city	0.98
7	Baunia Khal	North western part	8.8
8	Digun Khal	North eastern part	4.5
9	Mohakhali Khal	Central city	2.3
10	Hazaribagh Khal	South-western part.	0.7
11	Shegunbagicha khal	Central-eastern part	1.0
12	Manda khal	Central-eastern part	1.0
13	Shangbadik Colony	North western part	1.0
14	Section 2 to Digun Canal through Section 6 and Rupnagar	North western part	3.5
15	Mirpur Housing Canal	North western part	1.0
16	Kashaibari -Boalia to Balu river	North eastern part	3.0
17	Gerani khal	Central-eastern part	5.0

Figure 3: Table 1 :

Figure 4:

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Dhaka city area

Figure 5: Table 2 :

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	Cd	Cr	Cu	Mn	Fe	Pb
Cd	1.000					
Cr	-0.292	1.000				
Cu	0.227	-0.200	1.000			
Mn	-0.547	0.064	-0.109	1.000		
Fe	-0.207	-0.206	-0.048	0.860	1.000	
Pb	0.398	-0.282	0.768	-0.273	0.031	1.000

Figure 6: Table 3 :

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	Component	
	PC1	PC2
Cd	0.511	-0.525
Cr	-0.585	-0.113
Cu	0.812	-0.066
Mn	-0.140	0.968
Fe	0.184	0.927
Pb	0.890	-0.140

Figure 7: Table 4 :

.1 Conclusions

The present study showed that Cr, Cu and Pb were present as major pollutants in the some canals in the DCC area with high concentration levels, while Cd, Mn and Fe emerged as minor pollutants. Strong positive linear correlations were found between Mn, Cu and Pb from linear regression analysis. Principal component analysis summarizes (reduces) the data set into two major components representing the different interrelationship among the elements. Strong interrelation between Cu -Pb pair and Mn -Fe pair was found from principle component analysis. Corresponding cluster analysis result confirms the relationship between Mn -Fe metal pair but, does not confirm the strong interrelationship between the Cu -Pb metal pair. Comparison with USEPA guideline for sediment showed that Cr, Pb and Cu levels are in far excess of the recommended safe limits for some canals but pollutants concentration in the sludge are below the prescribed hazard limit for land application of sludge.

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