Assessing the Water Quality of Canals in Dhaka City, Bangladesh

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Abstract   Environmental degradation related to hazardous pollutants from economic activity became a major concern in many rapidly developing mega cities of the global South. In this study, the level of selected parameters (pH, TDS, TSS, TS, Alkalinity, Hardness, DO, BOD, COD, Na, Fe, Cr, Ni, Cd, Pb, Cl$^-$, Cu, and SO$_4^{-2}$, NO$_3^-$ and PO$_4^{-2}$) were measured to find water quality of canals in Dhaka City, Bangladesh. Samples were collected from 17 different canals in and around Dhaka City Corporation (DCC) area. Principal Component Analysis (PCA) and Cluster Analysis (CA) were used to assess the metal contamination of chemical parameters in the canals. Mean, Median, Minimum, Maximum and Standard Deviation were used to assess the variation of results of samples of canals. The analysis shows that in most of the samples physical and chemical parameters of hazardous materials were found. SO$_4^{-2}$, Cr, Cu and Pb were present as major pollutants with high concentration level, while Cl$^-$, Cd, Na and Fe emerged as minor pollutants. Further, TDS, Alkalinity and Hardness were found to increase alarmingly while BOD levels were found below the acceptable limit and rests were unchanged. Finally, data for the presence of metal in the canal sediments shows Cr and Pb levels were higher than the recommended sediment quality by both guidelines of Department of Environment (DoE), Bangladesh and the United States Environment Protection Agency (USEPA). From overall findings it is evident that sustaining environmental quality needs special attention to check hazardous pollutants in the water of canals in Dhaka.

Keywords   Water Quality, Pollutants, Physical Characteristics, Chemical Characteristics, Principal Component Analysis, Cluster Analysis

1. Introduction

The detrimental effects on soil ecosystems as well as its potential health risks are degrading due to accumulation of physical and chemical parameters [1,2]. Heavy metals among the parameters are necessary to plants at certain levels and exceeding its threshold can be toxic [2,3]. Sources of these elements in soils mainly include natural occurrence emerged from parent materials and anthropogenic and elements are non-biodegradable inevitably. Such elements coming from industrialization and agricultural activates, deposition, such as atmospheric deposition, waste disposal, waste incineration, emissions from traffic, fertilizer application and long-term application of waste water in agricultural land and are found to mix with water of different canals in and around Dhaka city [2,3,4,5].

Dhaka, the capital of Bangladesh is one of the most rapidly urbanized cities in the world with more than 20 million people in 2019 [6] and more than 21 million in 2020 [7] According to Canback Consulting of the Economist Intelligence Unit [8], it contributed around 40% of total Gross Domestic Product (GDP) of the country in FY2019-2020. Many industries have set up in and around the city during the last decade, and the number of new industries is continually increasing. The canals of Dhaka are increasingly being polluted with the city's thousands of industrial units and sewerage lines dumping huge volumes of toxic wastes day and night containing lot of heavy metals.

Heavy metals contamination in aquatic environment is of critical concern, due to toxicity of metals and their accumulation in aquatic habitats. Heavy metals pollute water of canals and mixes into global ecological system through rivers and seas which are the main pathways of natural water. Non-internment heavy metals mixed water has catenated to some severe human disease's such as malformation, kidney damage, cancer, abortion and so on even death in some cases of high concentration.

2. Methods and Materials

The methodology followed for this study includes utilization of data from both primary and secondary sources. Water samples were collected from 17 canals (Table 1 and

2) on the months of December, 2019 and January, 2020 and samples were analyzed for the parameters, pH, TDS, TSS, TS, Alkalinity, Hardness, DO, BOD, COD, Na, Fe, Cr, Ni, Cd, Pb, Cl⁻, Cu, SO_4^{-2}, NO_3^- and PO_4^{-2}. Above mentioned chemical and chemical characteristics concentration in the collected water samples were determined by total extraction with Aqua-Regia. Thus, primary data were collected.

Secondary data and information were collected from official and unpublished documents of various organizations including Bangladesh University of Engineering and Technology (BUET), Water and Sewerage Authority (WASA), Bangladesh Water Development Board (BWDB) etc. Published journals, thesis, annual reports and newspapers were also used. Analysis of primary and secondary data provided final results which are represented numerically and graphically.

The extracted aqueous solution was analyzed for selected parameters by using different types of instruments. Na, Cr, Cu, Ni, Cd and Pb were analyzed by Flame Emission Atomic Absorption Spectrophotometer (FL-AAS Model: Shimadzu, Japan, AA6800) and PO_4^{-2}, NO_3^-, SO_4^{-2} by Ion Chromatograph.

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 maxillofacial results were compared with the permissible safe levels for the water sample proposed by DoE. Multivariate statistical techniques [9,10,11,12,12,13,14,15] were adopted to assess the metal contamination in the water. For assessing water quality metal concentration was the primary assessment target. The established techniques of Pearson Correlation Analysis, Principal Component Analysis (PCA) and Cluster Analysis (CA) were used.

3. Canals of Dhaka

The total land area of Dhaka city is 300.00 sq.km [7] of which the surface water area is about 10-15% [16] (Figure 1).

Until only three decades ago, Dhaka had over 50 canals surrounded by four rivers-Buriganga, Balu, Turag, and Sitalakshya [17]. The major canal systems in and around the capital are the (i) Degun–Ibrahimur–Kallyanpur canal that drains out to the Turag River; (ii) Dhanmondi–Paribagh–Gulshan–Banani–Mohacanali–Begu nbari canal that drains out to the Balu River, and (iii) Segunbagicha–Jirani–Dholaicanal canal that drains out to the Balu and Buriganga rivers.

In 2004 a committee identified 43 canals of which 26 canals under Dhaka WASA was recommended as recoverable [18] The 26 canals are Kalyanpur main canal, Kalyanpur Ka, Kha, Gha, Uma and Cha canals, Katasur,

Ramchandpur, Abdullahpur, Diyabari, Digun, Gulshan-Banani, Mohacanali, Hazaribagh, Begunbari, Khilgaon-Basabo, Manda, Sutivola, Badda-Shahjadpur, Rupnagar, Baisteki, Kalshi, Bouniya, Ibrahimpur canals, Housing canal in Mirpur-14 and Jirani canal.
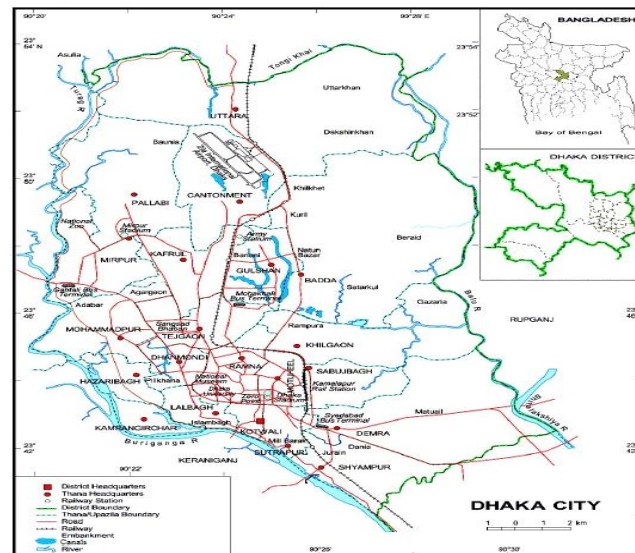

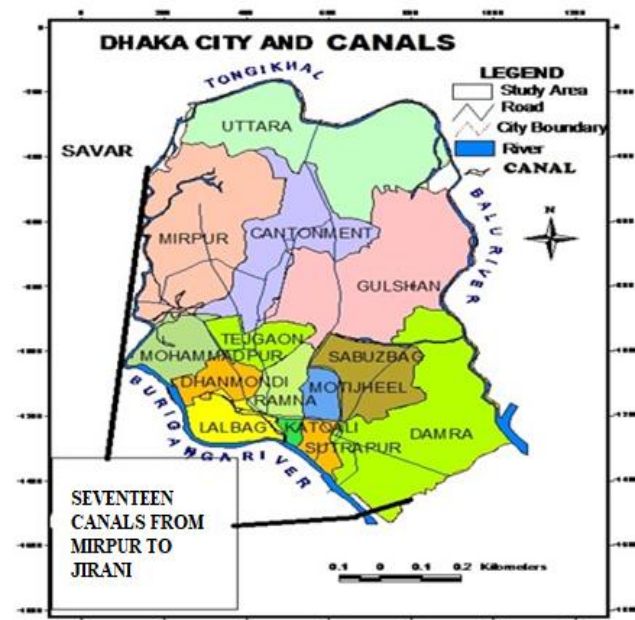**Figure 1.**   Map of the Dhaka City with Canals (*Source: Author*)

Figure 2.   Study area of canals of Dhaka City (*Source: Author*)

However, in 2019 field investigation for this research found only 17 canals have water flow within the area of Mirpur to Jirani of DCC (Figure 2).

Table 1 shows location and major characteristics of these 17 canals

Table 1. Major Canals in the DCC Area

SL No.	Canal's Name	Location (Part of the city)	Length (Km)	Latitude-N	Longitude-E
1	Kalyanpur main canal	Western	3	23°44'17"	90°20'25.5"
2	Kalyanpur branch canal - Ka	Western	1.5	23°44'41.3"	90°20'27.3"
3	Kalyanpur branch canal - Kha	Western	2.4	23°44'32"	90°20'39"
4	Kalyanpur branch canal - Gha	Western	1.56	23°44'38.9"	90°20'33.2"
5	Kalyanpur branch canal - Umo	Western	1.78	23°44'42.4"	90°20'32.2"
6	Kalyanpur branch canal - Cha	Western	0.98	23°44'43.1"	90°20'12"
7	Baunia canal	North western	8.8	23°48'2.9"	90°20'22"
8	Digun canal	North eastern	4.5	23°50'22"	90°21'35.2"
9	Mohacanali canal	Central city	2.3	23°44'42"	90°24'42.7"
10	Hazaribagh canal	South-western	0.7	23°42'23"	90°2'57'
11	Shegunbagicha canal	Central-eastern	1	23°20'12.3"	90°24'53.5"
12	Manda canal	Central-eastern	1	23°42'20"	90°28'30"
13	Shangbadik Colony	North western	1	23°47'47"	90°22'12"
14	Section 2 to Digun Canal through Section 6 and Rupnagar	North western	3.5	23°47'12"	90°20'12.5"
15	Mirpur Housing Canal	North western	1	23°48'20"	90°21'43.4"
16	Kashaibari - Boalia to Balu river	North eastern	3	23°51'48"	90°21'16.2"
17	Jirani canal	Central-eastern	5	23°42'30"	90°27'36.4"

Source: Author

Figure 3. Hazaribagh canal with waste water from tanneries (*Source: Author*)

Among the 17 canals of the study area Hazaribagh, Kalyanpur and Digun canal were found highly polluted due to high concentration of industries and population in surrounding areas. Particularly, in the Hazaribag tannery area wastes coming from nearby tanneries are mixed with the water of Buriganga River through Hazaribag sluice gate (Figure 3). There are about 196 tanneries in Hazaribag area from where more than 1600 m^3 tons of untreated and highly toxic effluents with a BOD$_5$ load of 17,600kg/day, an estimated 0.35 t/day of chromium is discharged into a lagoon of 25 ha and solid wastes are effused into canals every day [19]. Similarly, Mohakhali canal, Jirani canal and Segunbagicha canal also found polluted heavily with toxic pollutants mixing in the water from nearby industries.

4. Results and Discussions

The water sample analysis results for different chemical and physical characteristics are presented in table 2 and 3. The comparison between the metal concentration present in the water samples of DCC canals with permissible metal concentration limit proposed by DoE and USEPA for the water sample shows that some canals in DCC area are facing metal pollution at an alarming level.

In comparison with the USEPA guidelines it was found the water samples of Mohakhali Canal, Mirpur Housing Canal, Segunbagicha Canal, Jirani Canal are heavily polluted with Cu. Baunia Canal, Kalyanpur Shakha 'Gha' (Shewrapara), Segunbagicha Canal, Jirani Canal are heavily polluted with Cr. Furthermore, Pollution level of Pb in Mirpur Housing Canal is also exceeded the USEPA criteria.

Hazaribagh Canal, Kalyanpur "Kha" Canal, Kalyanpur main Canal, Digun Canal are comparatively low for all tested heavy metals except Cr. By reviewing the pollutant limits of USEPA against the result from water samples analysis, it can be easily stated that the pollutant concentration in the water of some canals are below the prescribed hazard limit for water application but some canals exceed the EPA guideline for heavily polluted water for some metals. The standard value for drinking water of USEPA is given below in table 4 and table 5.

Table 2.   Physical Parameters of Water in Canals of Dhaka city

Sr.	Canal's name and sampling location	Name of Physical Parameters									
		Tem (°C)	pH	TDS (mg/l)	TSS (mg/l)	TS (mg/l)	Alkalinity (mg/l) as CaCo$_3$	Hardness (mg/l) as CaCo$_3$	DO (mg/l)	BOD (mg/l)	COD (mg/l)
1	Hazaribagh canal (Sikder Medical)	21.3	6.7	27	1.9	28.9	403	287	Nil	Nil	22.3
2	Kalyanpur 'Kha' canal (Navana CNG pump)	22	6.5	132	0.2	132.2	296	9	2.4	1.2	17.2
3	Kalyanpur main canal (Darussalam)	18	6.7	143	0.4	143.4	219	13	3	2.2	19.6
4	Section-2 Digun canal (Rupnagar)	18.6	6.7	38	0.1	38.1	145	4	6.4	5.2	10.5
5	Baunia canal (Section-13)	19.2	6.7	76	0.2	76.2	270	7	2.4	1.0	12.5
6	Kalyanpur Shakha 'Gha" (Shewrapara)	22.2	6.6	142	0.3	142.3	260	124	3.2	1.8	12.5
7	Mohakhali canal (Near Bus Stand)	22.2	6.7	83	0.4	83.4	173	7	2.8	1.0	10.3
8	Mirpur Housing Canal (Mirpur-10)	22.1	6.7	76	0.2	76.2	248	8	5.8	3.8	12.6
9	Segunbagicha Canal (Kamalapur Stadium)	22.2	6.6	69	0.1	69.1	210	12	6.6	2.2	11.0
10	Jirani Canal (Kadamtola)	22.0	6.8	179	0.5	179.5	325	197	0.2	Nil	14.2
11	Kalyanpur branch Canal - Umo	22.4	6.7	175	0.3	175.3	218	7	4.0	2.8	10.3
12	Kalyanpur branch Canal - Cha	22.6	6.8	140	0.5	140.5	263	17	6.2	4.6	11.0
13	Manda canal	21.8	6.4	58	0.1	58.1	182	3	8.2	5.8	11.4
14	Shangbadik Colony	22.2	6.8	36	0.1	36.1	90	3	0.2	0.2	12.5
15	Kashaibari - Boalia to Balu River (Kashibari)	22.2	6.6	31	0.1	31.1	180	3	2.8	2.4	12.0
16	Section 2 to Digun Canal through Section 6 andRupnagar	22.1	6.7	38	0.1	38.1	360	7	0.4	0.2	12.5
17	Kalyanpur branch canal - Ka	21.8	6.8	143	0.2	143.2	250	9	2.4	1.8	11.0

Table 3.   Metal Concentration in Water Sample of Canals of Dhaka city

Sr.	Canal's name and sampling location	Metal concentration (mg/l)										
		Na	Fe	Cr	Ni	Cd	Pb	Cl$^-$	Cu	SO$_4^{-2}$	PO$_4^{-2}$	NO$_3^-$
1	Hazaribagh Canal (Sikder Medical)	430	2.0	62.3	Nil	0.3	1.4	5.2	3.7	132	20.4	14.2
2	Kalyanpur 'Kha' canal (Navana CNG pump)	130	1.2	79.0	0.1	Nil	12.7	0.9	7.0	400	1.2	13.6
3	Kalyanpur main canal (Darussalam)	142	1.2	41.9	0.1	0.1	0.2	1.0	1.9	520	2.0	13.4
4	Section-2 Digun canal (Rupnagar)	95	1.0	42.1	0.2	0.2	0.2	0.5	2.1	390	6.0	10.0
5	Baunia canal (Section-13)	104	1.0	121.3	0.1	0.1	0.1	0.5	6.1	410	6.0	3.90
6	Kalyanpur Shakha 'Gha" (Shewrapara)	213	1.0	231	0.1	0.1	2.7	2.0	6.2	592	2.0	12.6
7	Mohacanali Canal (Near Bus Stand)	197	2.0	75.7	0.2	0.3	48.2	2.0	116	120	3.0	13.4
8	Mirpur Housing Canal (Mirpur-10)	64	1.0	48.7	Nil	0.1	72.1	0.3	183	420	5.0	10.0
9	Segunbagicha Canal (Kamalapur Stadium)	102	1.0	80.4	Nil	0.1	22.5	0.2	171	385	4.0	3.40
10	Jirani Canal (Kadamtola)	258	2.0	72.3	0.2	0.2	34.1	2.0	301	150	7.9	23.8
11	Kalyanpur branch Canal - Umo	132	1.0	121	0.1	0.1	0.1	1.0	2.1	120	4.0	12.0
12	Kalyanpur branch Canal - Cha	134	1.0	75.2	0.1	0.1	0.2	1.0	1.9	380	4.0	12.7
13	Manda canal	67	1.6	192.3	0.3	0.2	67.2	0.4	3.7	420	6.0	12.0
14	Shangbadik Colony	130	1.0	48.2	0.1	0.3	0.1	0.3	2.1	500	6.0	10.0

Sr.	Canal's name and sampling location	Metal concentration (mg/l)										
		Na	Fe	Cr	Ni	Cd	Pb	Cl⁻	Cu	SO_4^{-2}	PO_4^{-2}	NO_3^-
15	Kashaibari - Boalia to Balu River (Kashibari)	228	1.0	45.5	0.1	0.1	0.1	0.2	4.9	390	3.0	10.0
16	Section 2 to Digun Canal through Section 6 and Rupnagar	167	2.0	45.2	0.2	0.2	0.2	0.4	2.9	440	4.0	6.0
17	Kalyanpur branch canal – Ka	103	1.0	74.9	0.2	0.1	.1	0.8	2.5	420	2.0	12.8
EPA Guideline for Sediments (mg/l)												
Not Polluted	……	<25		<25		<300		<40		……		
Moderately polluted	……	25-75		25-50		300-500		40-60		……		
Heavily Polluted	> 6	>75		>50		>500		>60		……		
EPA Limit for Land Application of Sludge (mg/l)												
		85	……	4300			……			840		……

Table 4. Standard Value for Drinking Water

Characteristic	Parameter	Bangladesh standard	Remarks
Physical characteristic	Total Suspended Solids	10 mg/l	Below
	Total Dissolved Solids	1000 mg/l	All
	Total Solids	1000 mg/l	All
	Temperature	20-30℃	All
	pH	6.5-9.2	All
	Alkalinity	50-200 mg/l as $CaCO_3$	Non permissible
	Hardness	200-500 mg/l as $CaCO_3$	Below
Chemical characteristics	Na	200 mg/l	Permissible
	Cl	0.2 mg/l	Above
	Fe	1.0 mg/l	Permissible
	Ni	0.1 mg/l	Permissible
	Cu	1.0 mg/l	High
	SO_4^{-2}	400 mg/l	
	PO_4^{-2}	6.0 mg/l	Permissible
	NO_3^-	10.0 mg/l	
Biological characteristics	Dissolve Oxygen	4-8 mg/l	Below
	Biological Oxygen Demand	Nil	-
	Chemical Oxygen Demand	Nil	-

Table 5. Standard Value for Drinking Water

Characteristic	Parameter	Bangladesh standard
Toxic substances	Lead	0.05 mg/l
	Cadmium	0.01 mg/l
	Chromium	0.05 mg/l

Source: USEPA

Laboratory test shows that the samples of all canals are below TSS, Hardness, DO while all samples are found above permissible limit for Pd, Cd and Cr. According to **Kentucky Water Watch** guideline, the samples of all canals are heavily polluted with chemical NO_3^-.

Prior to form 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 Hardness – TSS (r = 0.821), Hardness – Alkalinity (r = 0.635), BOD – DO (r = 0.924) and COD - TSS (r = 0.705), COD-Alkalinity (r = 0.544), COD - Hardness (r = 0.609) pairs (Table 6), indicating the existence of a common source/origin of these parameters in the water sample.

For Chemical characteristics, strong positive correlations were observed for Fe – Na (r = 0.576), Ni–Fe (r = 0.353), Cd – Na (r = 0.437) and Cd - Fe (r = 0.623), Cl⁻-Na (r = 0.878), Cl⁻-Fe (r = 0.559), Cu-Pb (r = 0.583), PO_4^{-2}-Na (r = 0.710), PO_4^{-2} -Cl⁻ (r = 0.767), NO_3^--Na (r = 0.434), NO_3^-—Cl⁻ (r = 0.485) pairs (Correlation matrix is shown in Table 7), indicating the existence of a common source/origin of these parameters in the sludge sample.

Table 6.   Correlation Matrix between Different Physical Parameter Pairs

Parameters	pH	TDS	TSS	TS	Alkalinity	Hardness	DO	BOD	COD
pH	1.000								
TDS	.206	1.000							
TSS	.171	-.088	1.000						
TS	.207	1.000	-.080	1.000					
Alkalinity	.075	.182	**.578**	.187	1.000				
Hardness	.160	.072	**.821**	.079	**.635**	1.000			
DO	-.446	-.015	-.358	-.018	-.416	-.464	1.000		
BOD	-.350	-.022	-.312	-.025	-.423	-.435	**.924**		
COD	-.048	-.019	**.705**	-.013	**.544**	**.609**	-.466	-.413	1.000

* 100% significant

Table 7.   Correlation Matrix between Different Metal Pairs

Parameters	Na	Fe	Cr	Ni	Cd	Pb	Cl	Cu	SO_4^{-2}	PO_4^{-2}	NO_3^-
Na	1.000										
Fe	**0.576**	1.000									
Cr	-0.085	-0.090	1.000								
Ni	-0.233	**0.353**	0.225	1.000							
Cd	**0.437**	**0.623**	-0.168	0.248	1.000						
Pb	-0.251	0.291	0.173	0.180	0.143	1.000					
Cl	**0.878**	**0.559**	0.076	-0.221	0.438	-0.094	1.000				
Cu	0.061	0.304	-0.157	-0.100	0.091	0.583	0.044	1.000			
SO_4^{-2}	-0.481	-0.544	0.181	-0.017	-0.382	-0.174	-0.532	-0.373	1.000		
PO_4^{-2}	**0.710**	0.486	-0.112	-0.213	0.600	-0.044	**0.767**	0.022	-0.483	1.000	
NO_3^-	**0.434**	0.411	0.024	0.275	0.168	0.171	**0.485**	0.352	-0.415	0.208	1.000

*95% Significant

To find a solid assessment hypothesis of different physical parameters may have common origin was insured through multivariate methods of static analysis [5]. In this research, two multivariate techniques were applied: Principal Component Analysis (PCA) and Cluster Analysis (CA).

The PCA has been considered as a useful tool for better understanding of the relationship among the variables (metal concentrations) and for revealing groups (or clusters) that are mutually correlated within a data body [2]. On the consequence's PCA is a smaller number of new independent variables reduce overall dimensionality of the correlated data where each of which is a linear combination of originally correlated variables. CA solely aligns a set of observations into two or more unknown groups based on combination of internal variables.

CA discovers a system of organized observation based on overall group membership that helps to define source profiles of different variables for example metal concentration and other inter-related interpretation in terms of possible parental sources [20]. Principal Component Analysis (PCA) using varimax normalized rotation was conducted for common source identification where the variables are correlated with two principal components in which 81.23% for physical and 79.01% for chemical

characteristics of the total variance in the data was found.

Table 8. Rotated Component Matrix for Physical Characteristics (Rotation Method: Varimax with Kaiser Normalization.)

Parameters	Component	
	1	2
pH	.282	.378
TDS	-.040	.978
TSS	.820	-.109
TS	-.033	.978
Alkalinity	.733	.199
Hardness	.841	.068
DO	-.772	-.122
BOD	-.738	-.121
COD	.784	-.074
% Eigen values	3.800	2.103
% of Variance	42.226	25.364
Cumulative %	42.226	65.590

For physical parameters, the rotated Principal Component Loadings are given in Table 8. Principle component plot in a rotated space is shown in Figure 4. The first component with 15.64% of variance comprises TSS, Alkalinity (bold figures in Table 8) with high loadings. This association

strongly suggests that these variables have a strong interrelationship. The corresponding Cluster Analysis Dendrogram is shown in Figure 5.
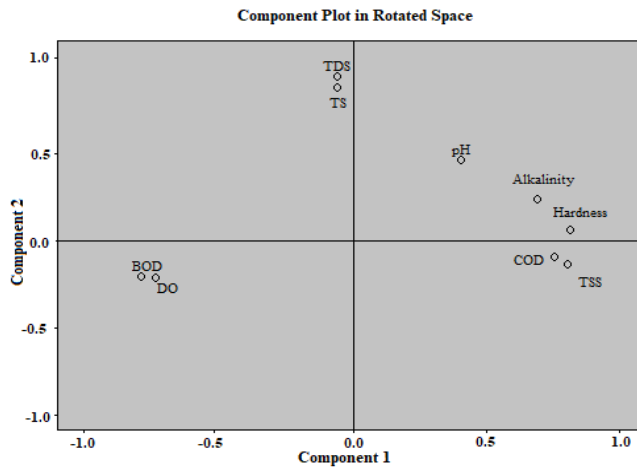

Figure 4. Principal Component in a Rotated Space for physical characteristics
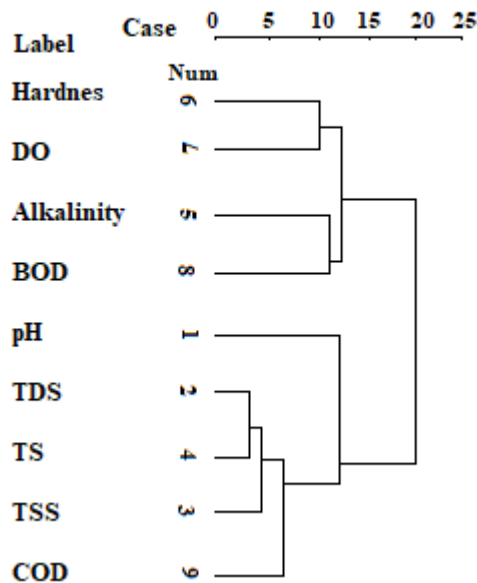

Figure 5. Dendrogram of Cluster Analysis for Physical Characteristics

From the Cluster Analysis result it can be said that there is a strong correlation between DO-BOD Physical parameter pair, which is a good agreement with PC2, but Cluster Analysis results did not show a good agreement between TSS-Alkalinity pair. This result suggests that the strong relationship between TSS-Alkalinity pair does not confirm. On the other hand, the rotated Principal Component Loadings are given in Table 9. Principle component plot in a rotated space is shown in Figure 6. The first component with 38.092% of variance comprises Na, PO_4^{-2} (bold figures in Table 9) with high loadings. This association strongly suggests that these variables have a

strong interrelationship. The second component (PC2) contributes Cu and Pb at 3.31% variance which also infers the strong correlation between this metal pair. The corresponding Cluster Analysis Dendrogram is shown in Figure 7. From the Cluster Analysis result it can be said that there is a strong correlation between Na- PO_4^{-2} heavy metal parameter pair, which is a good agreement with PC2, but Cluster Analysis results did not show a good agreement between Cr-NO_3^- pair. This result suggests that the strong relationship between Ni-SO_4^{-2} pair does not confirm.
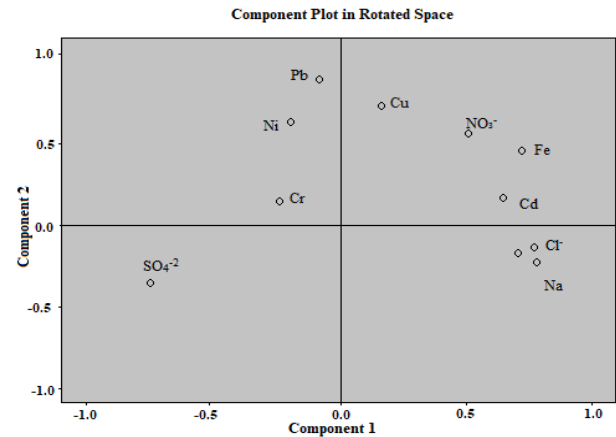

Figure 6. Principal Component in a Rotated Space for Chemical Characteristics
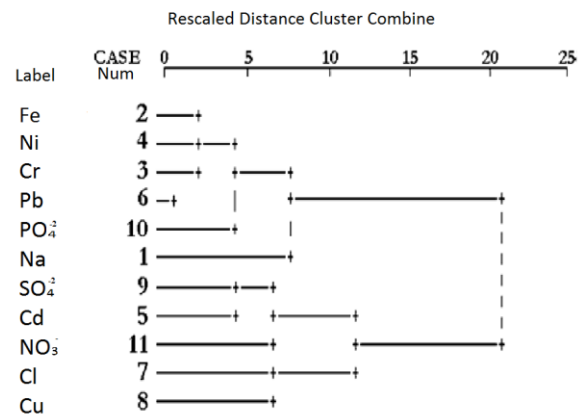

Figure 7. Dendrogram of Cluster Analysis for Chemical Characteristics

5. Conclusions

According to the standard value of the water, the analyses indicate serious pollution of water in canals of Dhaka city. Therefore, these canals are found not suited for fish and other aquatic animals and also highly hazardous to human health. Analysis found lower range of TSS, TDS, COD etc. from the standard value and linear regression analysis shows strong positive linear correlations among TDS, TSS and DO & SO_4^{-2}, Cu and Pb. Cr, Cu & Pb were found as major pollutants in some canals.

Table 9. Rotated Component Matrix for Chemical Characteristics (Rotation Method: Varimax with Kaiser Normalization.)

Parameters	Components	
	1	2
Na	.905	-.215
Fe	.720	.469
Cr	-.163	.124
Ni	-.111	.562
Cd	.649	.220
Pb	-.051	.822
Cl	.911	-.132
Cu	.172	.669
SO_4^{-2}	-.685	-.311
PO_4^{-2}	.851	-.167
NO_3^-	.492	.438
% of Eigen Value	4.190	2.009
% of Variance	38.092	18.259
Cumulative %	38.092	56.352

Principle Component Analysis (PCA) shows strong interrelation between Cl^- - Na pair and PO_4^{-2} – Cl^- pair in chemical characteristics. Cluster Analysis (CA) confirms relation between Na-Fe but not in Cl^--Na metal pair. Comparing with standard guideline of USEPA, Cr, Pb and Cu levels are not fulfilled.

Strong interrelation between BOD - DO pair and Hardness - TSS pair was found from Principle Component Analysis. Similar to Chemical Characteristics analysis, corresponding Cluster Analysis result confirms the relationship between COD–TSS pair but do not confirm the strong interrelationship between the Hardness – TSS pair. So, in most canals BOD, DO and TS levels are far from safe limit and hazardous for any physical use.

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Disclosure

This paper is based on primary research conducted by the author, it is not submitted or published anywhere. Findings of the research can be used for varied purposes based on users own responsibility.

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