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Evaluation of Surface Water Quality of Surma River Using Factor Analysis

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Abstract— **In this study, the factor analysis technique is applied to surface water quality data sets obtained from the Surma River Basin, Sylhet, Bangladesh during three different hydrological periods. Results show that the indices which changed the quality of water in two seasons and locations differed. During summer, monsoon and winter season pollutants mainly originated from industrial source and 38.464% of total variance is explained by the industrial factor. Thus, major pollution threats over the year are industrial uses which are defined as point pollution source. Besides this, agricultural and organic pollutants are also observed as threats for the river water quality which are defined as non-point pollution sources. This study shows that factor analysis is a useful method for decision makers in determining the extent of pollution via practical pollution indicators.**

INTRODUCTION

Water quality monitoring has one of the highest priorities in environmental protection policy [8]. The quality of water is identified in terms of its physical, chemical and biological parameters [7. The particular problem in the case of water quality monitoring is the complexity associated with analysis the large number of measured variables [6]. Reference [5] reported that the sensitivity of DO deficit in waste water is about 65 times less than that of a sensitive parameter like re-aeration rate. Further with wastewater treatment the reduction in DO in treated wastewater is very marginal. Multivariate statistical methods including factor analysis have been used successfully in hydrochemistry for many years. Surface water, ground water quality assessment and environmental research employing multi-component techniques are well described in the literature [9]. Multivariate statistical approaches allow deriving hidden information from the data set about the possible influences of the environment on water quality. Factor rotation is used to facilitate interpretation by providing a simple factor structure [12]. Factor analysis attempts to explain the correlations between the observations in terms of the underlying factors, which are not directly observable [11]. There are three stages in factor analysis [4]-

1. For all the variables a correlation matrix is generated.
2. Factors are extracted from the correlation matrix based on the correlation coefficient of the variables.
3. To maximize the relationship between some of the factors and variables, the factors are rotated.

The objectives of the study are to assess the present water quality parameters and to find out the leading parameters responsible for increasing or reducing the pollution intensity of the river water during three different seasons covering a whole year.

STUDY AREA

Sylhet City Corporation occupies a total area of 26.5 sq. km with a population of around 0.5 million [3]. The water samples were collected from the estuaries of 6 different points. These are: Kochai, Monipur Ghat, Shahjalal Bridge, Kin Bridge, Kajir Bazar, Tuker Bazar. Among these Shahjalal Bridge, Kin Bridge and Kajir Bazar are located at the heart of sylhet city. On those points some natural canals met to Surma River which is Mongoli Chara, Balram Chara and Guali Chara. There are many rice mills are situated from the area of Shahjalal Bridge to kajir bazar. On the other hand Toker bazaar and Kochai is outside the city. In toker bazaar a natural canal meets to surma basin named Mora gang and kochai is located near to the natural canal Khushi Khal. The positions of the sampling stations and the natural canals network of the sylhet city are shown in fig. 1.

METHODOLOGY

The water samples were collected from six different locations (at the estuaries) of the Charas. Sampling points are shown in fig. 1. Water samples were collected at the first week of every month of a year (from March 2008 to February 2009). It was ensured that the plastic bottle used for sampling was packed by tape to make the sample free from air contact. The portable pH meter HI 8014 by HANNA Instrument was used to test pH. For Turbidity testing, Microprocessor Turbidity Meter HI 93703 by HANNA Instruments was used. PO_4, NO_3 were tested using HACH UV Spectrophotometer DR/ 4000U. Suspended Solids, Dissolved Solids, Dissolved Oxygen, BOD_5 were tested by Standard Methods developed by reference [2]. All tests were performed in the Water Supply and Sewerage Engineering Laboratory, Department of Civil and

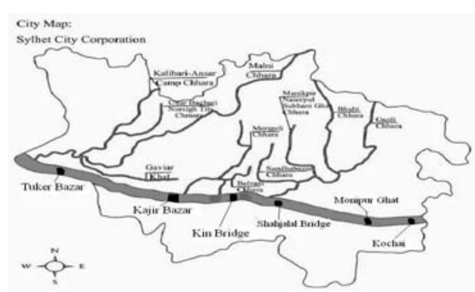

Fig. 1: Location of charas and sampling points.

Environmental Engineering, SUST, Sylhet. The statistical package for the social sciences software [10] for windows was used in this study. The selected parameters for the estimation of surface water quality characteristics were: pH, electrical conductivity (EC), total suspended solids (TSS), total dissolved solids (TDS), hardness, calcium (Ca^{++}), magnesium (Mg^{++}), alkalinity, chloride (Cl^-), Sulphate (SO_4^{2-}), nitrite (NO_3), nitrate (NO_2), phosphate (PO_4), fluoride (Fl^-), Salinium (Sl^-), potassium (K^+), detergents, iron (Fe^{3+}), cobalt (Co^{2+}), zinc (Zn^{2+}), lead (Pb^{3+}), cadmium

(Cd^{2+}), dissolved oxygen (DO), chemical oxygen demand (COD), bio-chemical oxygen demand (BOD).

Table I: Total and cumulative percentage of variance for summer season

Component	Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	10.770	38.464	38.464	10.493	37.477	37.477
2	1.617	5.775	44.239	1.868	6.670	44.147
3	1.531	5.469	49.708	1.557	5.561	49.708

RESULT AND DISCUSSION

The overall water quality data has been analyzed season-wise such as summer, monsoon and winter. The overall assessment of water quality has been discussed below.

Summer Season

Factor analysis was applied to data sets obtained during summer season (April to July). Total and cumulative percentage of variance for summer season were calculated based on descriptive statistics of the data set, percent total variance and the rotated component matrix and presented in table I and presented in fig. 2. From the figure it is clear that lead was increased and increased the pollutant concentration of the river water. On the other hand, Phosphate was reduced as well as reduced pollution intensity of the river water.

The correlation matrix variables was generated and factors extracted by the cancroids method, rotated by varimax rotation .The factor analysis generated three significant factors which explained 49.71% of the variance in data sets. The following factors were indicated considering the hydro chemical aspects of the water.

Factor 1(Industrial Factor=F1): Among the leading parameters under this factor Cobalt, Nickel and Total Suspended Solids (TSS) have the positive impacts i.e. these three parameters were increased and also increased the pollution of the river water under this period (April to July). On the other hand, Cadmium and Zinc were reduced and also reduced the pollutant concentration of the river.

Factor 2 (Agricultural Factor=F2): Among the leading parameters under this factor Manganese and Potassium were increased and also increased the pollution of the river water. Nitrite was reduced as well as reduced the pollution intensity.

Factor 3 (Organic pollution factor=F3): Among the leading parameters under this factor Calcium, Sulphate, COD and lead was increased and the pollutant concentration of the river water was also increased. On the other hand, Phosphate was reduced the pollution intensity of the river.

Monsoon Season

Total and cumulative percentage variance for monsoon season was evaluated from Descriptive Statistics for

Factor 1: Among the leading parameters under this factor Cobalt and Nitrite have positive impact i.e. these two parameters were increased and also the pollutant concentration of the river water was increased. On the other hand, Nickel and Alkalinity have negative impact i.e. these two parameters were decreased as well as reduced the pollution intensity of the river water.

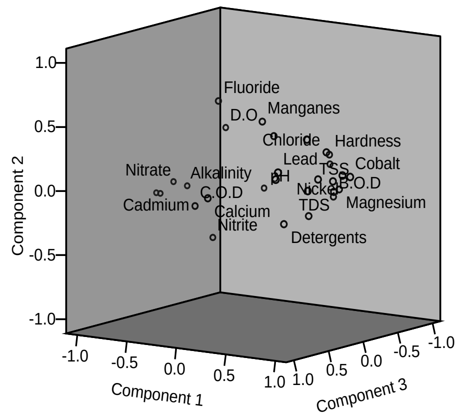

Fig. 2: Component plot in rotated space for summer season

Table II: Total and cumulative percentage variance for monsoon season.

Component	Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.441	31.263	31.263	8.273	30.641	30.641
2	1.660	6.147	37.411	1.724	6.386	37.027
3	1.458	5.400	42.810	1.561	5.783	42.810

Factor 2: Among the leading parameters under this factor Copper and Sulphate have positive impact i.e. these two parameters were increased and hence the pollution intensity of the river water is increased. On the other hand, Calcium and Zinc have negative impact i.e. these two parameters were decreased as well as reduced the pollution intensity of the river water during this period.

Factor 3: Among the leading parameters under this factor Phosphate and Fluoride have positive impact i.e. these two parameters were increased with the pollution intensity of the river water over the period. On the other hand, Hardness has the negative impact i.e. it is decreased over the season as well as reduce the pollution intensity of the river water.

Winter Season

Descriptive statistics, total variance and cumulative variance values are calculated and total and cumulative percentage variance for winter season is presented in table III. Three factors are indicated below explained 40% of total variance.

Factor 1: Among the leading parameters under this factor Cadmium has positive impact i.e. It is responsible for the increasing pollution of the river water over the season. On the other hand, Nickel and Manganese have the negative impact i.e. they are responsible for reducing the pollution intensity of the river water over the season.

Factor 2: Among the leading parameters under this factor only Nitrate has positive impact i.e. it is responsible for the increasing of pollution intensity of the river water over the season. On the other hand, Chloride and EC have the negative impact i.e. they are responsible for reducing pollution intensity of the river water over the season.

Factor 3: Among the leading parameters under this factor Nitrite and COD have the positive impact i.e. they are responsible for increasing the pollution intensity of the river water over the season. On the other hand, DO, Phosphate and Magnesium have the negative impact i.e. they are responsible for reducing pollution intensity of the river water over the season.

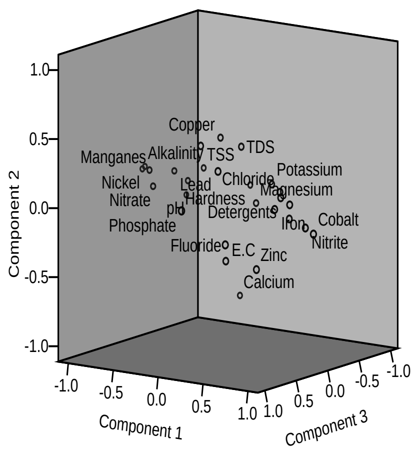

Fig. 3: Component plot in rotated space for monsoon season.

Table III: Total and cumulative percentage variance for winter season.

Component	Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.487	27.729	27.729	7.128	26.401	26.401
2	1.779	6.591	34.320	1.906	7.059	33.461
3	1.534	5.680	40.000	1.766	6.539	40.000

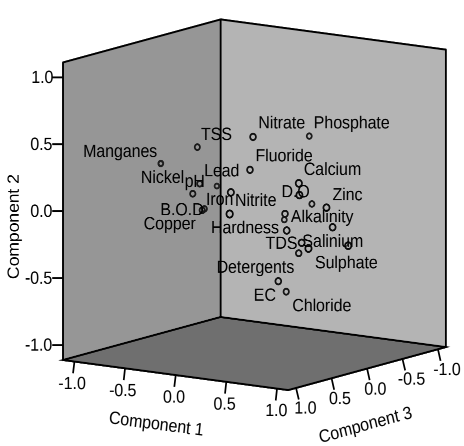

Fig. 4: Component plot in rotated space for winter season

CONCLUSION

The factors indicative of water quality in different hydrological periods and locations differed in the River Surma Basin. During summer, monsoon and winter season pollutants mainly originated from industrial source and 38.464% of total variance is explained by the industrial factor. Thus, major pollution threats over the year are industrial uses which are defined as point pollution source. Besides this, agricultural and organic pollutants are also observed as threats for the river water quality which are defined as non-point pollution sources. Therefore priority should be given to minimization of these sources to improve water quality in the basin. This study shows that factor analysis is a useful method that could assist decision makers in determining the extent of pollution via practical pollution indicators. It could also provide a crude guideline for selecting the priorities of possible preventive measures in the proper management of the surface water resources of the basin.

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