

Assessment of Water Quality Using Multivariate Factorial Analysis in Brahmani River, India

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Abstract River Brahmani is reported to be polluted from the effluents discharged from the nearby industries, towns and villages located near the banks. Presence of heavy metal content and radioactive material makes it more unsuitable for human use. Besides, the fertilizers used for agricultural purpose affect the pH and nitrate content of water. In this study, the factor analysis and principal component analysis applying the Multivariate Factorial Analysis (MFA), a statistical technique by SPSS are used to water quality data sets of the Brahmani River Basin. It analyses the surface water contamination and determines the correlations between water quality parameters such as pH, DO, BOD, Conductivity, Nitrate-N, NH₃-N, TA as CaCO₃, and TH as CaCO₃. The statistical analysis is done by the available monthly data of five gauging stations of the River from 2003 to 2012. The result shows the four extracted principal components which reflect the information of primitive variables as well as the main pollution indicators. The technique using SPSS is believed to be useful tool in identifying practical pollution indicators for delineating the domestic and agricultural pollution in the River. It also helps the local decision-makers on the suitable management of the surface water quality within the River Basin.

Keywords Brahmani, Correlation, Factor Analysis, MFA, Principal Component Analysis, SPSS

1. Introduction:

Water availability means the ideal combination of quality groundwater and surface water resource taken together at a locality. While rivers form the lifeblood of most of the cities, towns and villages across the country, there is a tremendous variation both in the quantity and quality of discharge from location to location in a river reach. With a few exceptions, all the medium and minor river basins originates in the mountains, and thus exhibit a common features of fast flowing and monsoon-fed in the hilly regions and by the time they reach the plains they are tidal. The treated or untreated discharges from such sources would always find a way into the rivers that oscillate like a pendulum due to seasonal flow character of these rivers. During monsoon, when rain water flows down the river the discharged pollutants get flushed out by upland flow. As the discharge location moves downstream, then flushing out time for pollutants decreases exponentially. Surface water of River Brahmani is found extremely variable in its chemical composition due to seasonal variations in relative contributions of ground water and surface water sources. The mineral content in river water usually bears an inverse relationship to discharge which tends to increase from source to mouth, although the increase may not be continuous or uniform. Other factors like discharge of city wastewater, industrial waste and mixing of waters can also affect the nature and concentration of minerals in surface water.

Multivariate analysis (MVA) is based on the statistical principle of multivariate statistics, which involves observation and analysis of more than one statistical outcome variable at a time. The application of different multivariate applications such as factor analysis and principal component analysis are used for interpretation of those complex data matrices with the better assessment of water quality and ecological status of surface water systems [3]. Boyacioglu, Boyacioglu and Gunduz (2005) applied the factor analysis to the surface water analyzing the surface water contamination and determined the correlation between water quality parameters [1]. The principal component analysis technique was employed to evaluate the seasonal correlations of water quality parameters, while principal factor analysis technique was used to extract the parameters that are most important in assessing seasonal variations of river quality [6]. Yang, Linyu and Shun (2009) stated multivariate statistical techniques including cluster analysis (CA), principal component analysis (PCA), factor analysis (FA) and discriminate analysis (DA), were used to evaluate temporal and spatial variations and to interpret a large and complex water quality data [7].

2. Study Area and Pollution Sources:

The Brahmani River Basin has a total drainage area of 39,268 km² of which 22,516 km² is in the state of Odisha, 15,405 km² is in Jharkhand and the balance 1347 km² in Chhattisgarh. The Panposh gauging station can be located in the Sundargarh district in Odisha with drainage area of approximately 5718 km² in the district. The Angul district in Odisha drains 6375 km² into the basin that locates the Talcher up-stream station. The Kendrapada district drains 1114 km²; a small basin includes the gauging stations named Aul and Pottamundai. Likewise, the Dhenkal district drains 3969 km² into the River Basin includes the gauging station Kamalanga downstream. The land use statistics have been compiled using district level records collected from the co-basin States. Information has been processed sub-basin wise as well as for the total basin. The aggregated land use as derived from the latter analysis is presented in Table.1.

Drainage area of River Brahmani in Odisha constitutes 57.63% of the total basin area. In this portion of the catchment, some large industries are located that have good effluent treatments plants (ETP) and the treated wastewater, unless completely recycled or reused discharges into some tributaries, which ultimately drains into the River.

A notable development in the pollution control measures during the last 5 to 6 years is complete recycling of the overflow from the ash ponds of the coal based Thermal Power. A list of large industries operating in the Basin is given in Table 2.

Table 1: Land Use Pattern in the Brahmani River Basin (CPSP, 2005)

Geographical Area	39,268km ²
Forests	15,101 km ²
Permanent pastures	1,323 km ²
Land not available for cultivation, waste and fallows	9,805 km ²
Land under reservoirs	607 km ²
Culturable land (Cultivated Land, Cultivated wastes & Fallow)	21,805 km ²
Net sown area	12,432 km ²

Table 2: Major Industries in the Brahmani River Basin (OPCB, 2006)

<i>Name of Industry</i>	<i>Products</i>
Rourkela Steel Plant(RSP)	Iron and steel ,Chemicals and Fertilizers
RSP Captive Power Plant(CPP),Rourkela	Power
IDL Chemicals, Rourkela	Slurry Explosives
national aluminum company(nalco)	aluminum
NALCO-CPP, Angul	Power
National Thermal Power Corporation(NTPC), Talcher	Power
NTPC Super Thermal Power plant, Talcher	Power

The average values for various parameters are listed out and compared with permissible limit prescribed by IS: 10500 in Table.3. Five gauging stations as shown in Fig. 1 namely, Panposh downstream, Talcher up-stream, Kamalanga downstream, Aul and Pottamundai are selected on the basis of mining and industrial activities prevalent nearby. From these five gauging stations, the data are sampled during 2003-2012 for monsoon season. Eleven water quality parameters such as pH, Dissolved oxygen (DO), Biological Oxygen Demand (BOD), Conductivity, Nitrogen as Nitrate (Nitrate-N), Total Coli-form (TC), Fecal Coli-form (FC), Chemical Oxygen Demand (COD), Ammonia as Nitrogen (NH₄-N), Total Alkali as CaCO₃ (TA as CaCO₃) and Total Hardness as CaCO₃ (TH as CaCO₃) are used for the further multivariate analysis.

Figure.1. Map shows the Locations Gauging Stations of Brahmani River



Table 3: Comparison of water quality parameters of River Brahmani with IS: 10500

Water Quality Parameters	Panposh d/s	Talcher u/s	Kamalanga d/s	Aul	Pottamundai	Permissible Limit IS:10500
pH	7.48	7.48	7.61	7.44	7.53	6.5-8.5
DO (mg/l)	6.92	7.52	7.28	7.03	6.75	30-100
BOD (mg/l)	3.43	1.36	2.06	1.42	1.32	0-5
Conductivity (mmho/cm)	195.44	124.33	148.31	138.11	173.13	0-300
Nitrate-N (mg/l)	1.94	1.23	0.99	0.42	0.65	45-100
TC (MPN/100 ml)	22544.44	6585.56	7611.11	12622.22	9437.04	490-24000
FC (MPN/100 ml)	11697.41	2862.59	4541.11	5062.93	4283.70	110-54000
COD (mg/l)	29.36	12.90	16.78	12.86	11.43	0-250
NH ₄ -N (mg/l)	1.10	0.73	0.83	0.86	0.91	0-50
TA as CaCO ₃ (mg/l)	55.07	51.41	53.52	51.11	54.93	200-600
TH as CaCO ₃ (mg/l)	84.63	69.33	55.52	53.89	57.15	300-600

3. Multivariate Analysis:

3.1. Factor Analysis

Factor analysis is a multivariate statistical method used to describe variability among observed, correlated variables in terms of a potentially lower number of unobserved variables called factors. These multivariate patterns help to classify the original data. The first step of multivariate analysis is to standardize the raw data. Let $x_1, \dots, x_p$ denote p variables, each with N observations. The j th observation of the i th variable is X_{ij} , where $i=1, \dots, P$ and $j=1, \dots, N$. If x_m and S_i denote the mean and standard deviation respectively, the i th variable and the j th observation of the i th variable from the N observations is expressed in standardized unit given as:

$$Z_{ij} = \frac{X_{i,j} - x_m}{S_i} \quad (1)$$

where Z_{ij} is the j th value of the standardized variable Z_i .

The mean and variance of Z_i are 0 and 1 respectively for all values of i . Standardization tend to increase or decrease the influence of variables which indirectly proportional with the variances. Standardization also eliminates the measurement units over the analysis.

In the second step of multivariate factorial analysis, the correlation coefficients are evaluated by dimension reduction and are presented in a matrix format (Lewis-Beck, 1994). The correlation analysis rearranges the structural matrix for its better explanation and understanding. Correlation coefficient measures the relationship between each constituent by the variance. The correlation coefficient is given as:

$$r_{x,y} = \frac{(x - x_m)(y - y_m)}{\sqrt{[(x - x_m)]^2 [(y - y_m)]^2}} \quad (2)$$

Where x_m and y_m are the mean values of x observations and y observations respectively. Table.4 represents the correlation matrix of the parameters in five gauging stations at the Brahmani River Basin.

Table.4. Correlation Matrix for Water Quality parameters in Brahmani River Basin

	pH	DO (mg/l)	BOD (mg/l)	Cond. mmho/ cm	Nitrate - N (mg/l)	TC (MPN /100 ml)	FC (MPN / 100 ml)	COD (mg/l)	NH4- N (mg/l)	TA.as CaCO3 (mg/l)	TH.as CaCO3 (mg/l)
pH	1.00										
DO (mg/l)	0.10	1.00									
BOD (mg/l)	0.07	-0.22	1.00								
Cond. mmho/cm	0.10	-0.35	0.30	1.00							
Nitrate-N (mg/l)	0.16	-0.04	0.30	-0.01	1.00						
TC (MPN/100 ml)	0.11	-0.25	0.30	0.33	-0.05	1.00					
FC (MPN/100 ml)	0.11	-0.17	0.43	0.36	-0.01	0.68	1.00				
COD (mg/l)	0.10	-0.19	0.75	0.32	0.21	0.32	0.40	1.00			
NH4-N (mg/l)	0.12	0.05	0.02	0.18	-0.16	0.12	0.12	0.11	1.00		
T. Alka. as CaCO3 (mg/l)	0.07	-0.14	0.13	0.21	0.05	0.05	0.04	0.16	-0.03	1.00	
TH as CaCO3 (mg/l)	0.13	0.03	0.34	0.20	0.37	0.18	0.23	0.46	0.08	0.28	1.00

Pearson correlation matrix was prepared within the studied parameters for the data in monsoon season of nine years and shown in Table.4. It is observed that parameters such as DO, Conductivity, Nitrate-N, TC, FC, COD, NH4-N and TH as CaCO₃ exhibit slight correlation with pH varies from 0.10 to 0.16. BOD shows slight and moderate correlation with Nitrate-N, TC and TH as CaCO₃ varies from 0.30 to 0.43 where as it shows significant correlation with COD of 0.75. Conductivity exhibits slight correlation with TC, FC and COD varies from 0.32 to 0.36. Nitrate-N shows slight correlation with TH as CaCO₃ of 0.37. As TC and FC are more related to each other, shows a moderate correlation of 0.68 and TC exhibit a slight correlation with COD of 0.32. FC shows a moderate correlation of 0.40 with COD. COD exhibit a moderate correlation of 0.46 with TH as CaCO₃. DO shows slight negative correlation with Conductivity of -0.35.

The strong correlation between some parameters could be due to changes in land use, mining, industrial activity and improper effluent discharge in the River. When parameters exhibit strong or moderate correlation with each other, the correlation characterizes the quality of water. Therefore, it is important to convert correlated parameters into uncorrelated parameters to represent effective relation between correlated water quality parameters. Multivariate analysis provides a suitable method to transform correlated parameters into uncorrelated components.

3.2. Principal Component Analysis (PCA)

The central idea of principal component analysis (PCA) is to reduce the dimensionality of a data set consisting of a large number of interrelated variables and the possible variation present in the data. This is achieved by transforming to a new set of variables, the principal components (PCs), which are uncorrelated, and which are ordered so that the first few retain most of the variation present in all of the original variables. Principal component analysis is an analytical technique whereby a complex data set containing p variables is transformed to a smaller set of new variables, which maximize the variance of the original data set. All of the new variables are independent, i.e., are not correlated with each other (whereas the original, untransformed variables may have been correlated to a lesser or greater extent). The new principal component (PC) axes ($Y_1, Y_2, \dots, Y_p$) are uncorrelated (e.g. Y_1 and Y_2 are perpendicular as shown in Fig. 2).

In principle, each of the principal components is a linear combination of the original X values for the p variables given as:

$$PC_1 = c_{11}X_1 + c_{12}X_2 + c_{13}X_3 + \dots + c_{1p}X_p \quad (\text{axis } Y_1)$$

$$PC_2 = c_{21}X_1 + c_{22}X_2 + c_{23}X_3 + \dots + c_{2p}X_p \quad (\text{axis } Y_2)$$

...

$$PC_p = c_{p1}X_1 + c_{p2}X_2 + c_{p3}X_3 + \dots + c_{pp}X_p \quad (\text{axis } Y_p) \quad (1)$$

where c_{ij} is the component score coefficient for variable j on PC axis Y_i , and X_j is the X score for variable j .

PCA converts a multivariate set of variables ($X_1, X_2, \dots, X_p$) to new variables ($Y_1, Y_2, \dots, Y_p$), which are uncorrelated with each other. The first principal component consists of a principal component coefficient (α_i) for each variable (p) such that there is maximal variance in the calculated score for each case (n); the factor score

for each case is calculated as $\alpha_1 X_1 + \alpha_2 X_2 + \dots + \alpha_i X_i + \dots + \alpha_p X_p$, where X_i is the centre value for the i th variable (X_i : mean X for the i th variable). The first principal component axis for the raw variables X_1 is now the new axis Y_1 . The second principal component consists of the next set of principal component coefficients (α_i) such that the variance remaining is maximal in the calculated score for each case (n), and there is no correlation between first and second principal component. Y_2 is the second principal component axis for X_2 . Further sets of principal components (third, fourth, etc.) can be calculated until no statistical significance can be attributed to that principal component (e.g. by χ^2 test).

In principal component analysis, the PCs of Eigen value greater than unity are generally considered to be significant which contain most of the variability of the original data set. Since the original loadings may not be readily interpretable, usually they are rotated until a 'simple structure' is achieved, that means each variable has very high factor loadings (as high as 1) on one of the PCs and very low factor loadings (as low as 0) on the other PCs. The communalities of each variable calculated before and after factor rotation will be the same. The varimax rotation method is popular among the researchers.

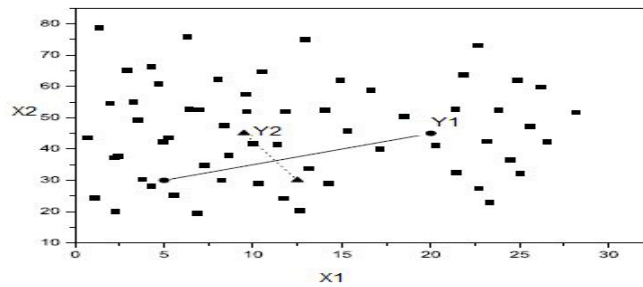


Fig 2: Graph of uncorrelated principal component axis

One of the most important steps of multivariate analysis is to determine number of factors that are extracted for the analysis of the data. The rotation of factor axis by SPSS is executed to get a simple structure such that some factors show high factor loadings for some variables and low factor loadings for others, which facilitates data interpretation in terms of original variables.

In order to extract the number of factors to be used for analysis, the variances and co-variances of the variables are analyzed. The Eigen values and Eigen vectors are evaluated for covariance matrix. The transformed factors by input data are extracted. Table.5 shows the Eigen value and percentages of variance associated with each factor obtained. The percentages of variance are summed to obtain cumulative percentages of variance.

Table.5. Eigen values, Percentages of Variances and Cumulative percentages of Variances

components	Total	% of Variance	Cumulative %
1	3.153	28.668	28.668
2	1.700	15.457	44.125
3	1.133	10.299	54.424
4	1.066	9.689	64.113
5	0.870	7.909	72.022
6	0.838	7.621	79.643
7	0.696	6.330	85.973
8	0.562	5.110	91.083
9	0.470	4.275	95.358
10	0.300	2.729	98.087
11	0.210	1.913	100.000

According to Kaiser in 1958 the components having Eigen value exceeding 1 are used for the further analysis [2, 4]. From the Table 5 four factors are used explaining 64.113% of total variance retained. Then, Kaisers varimax rotation method by SPSS is implemented to evaluate factor loadings that correlate the factors and parameter variables. The rotated factor matrix of these four factor model is created as shown in Table.6. These factor loadings are used to group the water quality parameters. The matrix also represents the most important information for interpreting the water quality parameters data.

Table.6. Loadings for Varimax Factor Matrix of Four Factor Model

Variable	Factors			
	1	2	3	4
pH	0.119	-0.315	0.029	0.014
DO (mg/l)	-0.101	0.189	-0.336	0.515
BOD (mg/l)	0.230	0.233	-0.073	-0.093
Cond. mmho/cm	0.102	-0.137	0.392	0.017
Nitrate-N (mg/l)	-0.012	0.387	-0.095	-0.201
TC (MPN/100 ml)	0.352	-0.133	-0.118	-0.015
FC (MPN/100 ml)	0.371	-0.071	-0.166	0.032
COD (mg/l)	0.194	0.235	0.000	0.062
NH ₄ -N (mg/l)	0.030	-0.115	0.091	0.702
TA as CaCO ₃ (mg/l)	-0.233	0.055	0.684	0.075
TH as CaCO ₃ (mg/l)	-0.014	0.332	0.146	0.290

It is observed from the Table.5 that four factors are extracted by varimax rotation of 64.113% of total variation is sufficient for the study. Factor 1 account for 28.668%, Factor 2 explains 15.457%, Factor 3 explains 10.229% and Factor 4 explains 9.689% of total variation. The factors in terms of actual parameters are given in equation 3 to 6.

$$F1=0.119*\text{pH}-0.101*\text{DO}+0.230*\text{BOD}+0.102*\text{Conductivity}-0.012*\text{Nitrate-N}+0.352*\text{TC}+0.371*\text{FC}+0.194*\text{COD}+0.030*\text{NH}_4\text{-N}-0.233*\text{TA of CaCO}_3-0.014*\text{TH of CaCO}_3$$

(2)

$$F2=-0.315*\text{pH}-0.336*\text{DO}+0.73*\text{BOD}-0.137*\text{Conductivity}+0.387*\text{Nitrate-N}-0.133*\text{TC}-0.071*\text{FC}+0.235*\text{COD}-0.115*\text{NH}_4\text{-N}+0.055*\text{TA of CaCO}_3+0.014*\text{TH of CaCO}_3$$

(3)

$$F3=0.029*\text{pH}+0.458*\text{DO}+0.018*\text{BOD}+0.392*\text{Conductivity}-0.095*\text{Nitrate-N}-0.118*\text{TC}-0.166*\text{FC}+0.000*\text{COD}+0.091*\text{NH}_4\text{-N}+0.684*\text{TA of CaCO}_3+0.146*\text{TH of CaCO}_3$$

(4)

$$F4=-0.014*\text{pH}+0.515*\text{DO}-0.093*\text{BOD}+0.017*\text{Conductivity}-0.201*\text{Nitrate-N}-0.15*\text{TC}+0.032*\text{FC}+0.062*\text{COD}+0.702*\text{NH}_4\text{-N}+0.075*\text{TA of CaCO}_3+0.290*\text{TH of CaCO}_3$$

(5)

4. Results and Discussions

The 150 data set of five gauging stations of Brahmani River in the months of monsoon from July to September are collected from 2003 to 2012. As discussed above in Table.5, the Eigen values, the percentages of variance and the cumulative variances shows that the first four factors explains 64.113% of total variance. The number of factors justified for the study can be judged from scree plot shown in Figure 2. This value of cumulative variance shows a good value for multivariate factor analysis by four factor model.

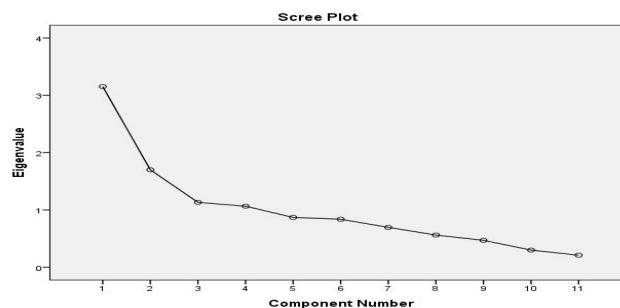


Figure.2. Scree Plot of 11 Water Quality Parameters

Factor 1 explains 28.668% of the total variance (Table.5). It reveals from Table.6 that factor 1 shows positive correlation with pH, BOD, Conductivity, TC, FC, COD and NH₄-N. These positive loadings represent a correlation between each parameter with other one. These findings reflect a negative influence

on surface water quality of River Brahmani by industrial effluents on the banks of the River and could be considered as 'inorganic contamination'. Factor 2 explains the 15.457% of the total variance (Table.5) with positive loadings on DO, BOD, Nitrate-N, COD, TA as CaCO_3 and TH as CaCO_3 . The relationship between these variables reflects the significance of domestic waste water discharges and could be identified as 'organic contamination'. Likewise Factor 3 and Factor 4 show positive loadings with the water quality parameters. The loadings of varimax rotation matrix as given in Table.6 are shown in Figure.3 explaining factor score projections of data onto corresponding eigenvectors.

Figure.3 Factor Score Projection of Four Factors

The factor model of station wise factor scores from 150 data sets are calculated using the equations 2 to 5 as discussed above.

Table.7. Scores of the Four Factor Model

PC1	PC2	PC3	PC4	PC1	PC2	PC3	PC4
0.808	0.760	1.813	0.742	-0.150	-0.709	-0.218	0.322
-0.515	1.718	0.382	2.416	-0.099	-0.704	-0.523	0.575
2.452	0.186	1.394	0.869	0.005	-0.848	-0.562	0.257
1.241	2.943	-1.669	0.225	0.522	-0.451	-1.401	-0.604
2.339	-0.061	-0.788	-0.894	0.717	-0.755	-0.919	-0.328
1.061	0.814	0.055	0.572	-0.764	-0.088	-0.197	-0.850
-0.744	2.283	5.283	-0.158	-0.698	0.081	-0.641	-0.512
0.734	1.717	2.493	-1.224	-0.504	1.182	-0.659	0.073
2.464	0.401	-0.899	-0.752	-0.610	0.023	0.102	0.161
1.359	0.360	2.351	-1.013	-0.333	-0.845	-0.214	-0.829
-1.009	1.863	-0.582	-0.002	-0.319	-0.753	-0.736	0.826
-0.787	1.001	-0.454	1.647	-0.289	0.313	-1.387	0.636
-0.799	0.266	0.048	0.057	3.289	-2.502	-0.687	-0.677
-0.823	-0.271	-0.348	1.308	0.120	-0.433	-0.535	-2.487
-0.073	-0.852	-1.453	-0.278	-0.108	-0.734	0.447	-2.585
-0.279	-1.091	-2.009	0.610	-0.791	0.095	0.128	-0.852
-0.727	-0.049	-1.024	-0.672	-0.444	-0.306	0.511	-0.910
-0.726	-0.176	1.229	0.043	0.004	0.215	-0.005	-0.856
-0.097	-0.309	-0.442	-0.865	-0.692	-0.498	0.534	0.085
-0.244	-0.500	-0.079	-0.254	-0.284	-1.083	0.737	0.011
-0.669	1.401	0.469	-1.099	-0.409	-0.773	0.025	-0.407
-0.302	0.448	0.723	0.304	-0.989	-0.351	-0.735	0.344
-0.066	0.278	0.436	-0.147	-0.359	-0.526	-0.066	1.957
-0.764	-0.749	0.429	0.442	0.278	-1.047	1.160	-1.560
-0.029	-0.829	-0.660	-0.742	0.167	-1.208	1.432	-1.386
0.321	-0.840	-0.913	0.459	0.742	0.715	0.100	0.243
-0.379	0.601	-0.454	-0.326	-1.255	1.929	-0.616	-0.332
-0.116	0.330	-0.858	-0.290	1.199	3.137	-0.193	-2.002
-0.083	-0.947	-1.678	-0.793	1.023	2.176	-0.590	-0.726
-0.045	-0.941	-1.066	-1.245	0.562	-0.061	-0.118	1.011
-0.492	-0.885	0.096	-0.701	0.496	0.573	-0.143	0.795
-0.540	-0.818	-0.087	-0.892	1.086	1.769	0.021	0.779
0.384	-0.177	-0.974	-0.891	4.665	-0.125	-0.055	1.715
-0.767	-1.398	-0.004	0.126	3.015	-0.210	-0.418	-0.257

-0.659	-0.687	0.023	1.147	2.960	0.270	0.217	-0.118
-0.486	-0.857	0.519	0.436	-0.818	1.283	-0.970	-0.333
-0.192	-0.972	0.043	-0.970	-0.883	1.232	-0.993	-0.238
0.047	-1.040	-0.191	-0.356	-0.842	1.941	-0.792	0.338
-0.132	-0.089	-0.339	-0.654	-0.695	0.526	-0.298	1.293
-0.106	-0.376	-0.125	-0.948	-0.663	-0.189	-0.719	0.967
-1.412	0.667	1.074	0.425	-0.523	-0.079	-0.527	0.588
-0.816	-0.130	1.075	1.284	-0.746	-0.446	-0.579	-0.006
2.368	-2.241	4.519	-0.084	-0.576	-0.195	0.773	1.444
-0.828	-0.873	1.267	1.327	-0.212	-0.104	2.663	-0.781
-0.655	-0.798	1.145	-0.680	-0.014	0.335	1.488	-1.111
-0.265	-0.944	-1.348	-0.418	-0.891	0.788	0.014	-1.211
-0.432	-0.439	-0.356	-0.944	-0.811	0.883	-0.113	-1.273
-1.582	0.185	2.174	0.819	0.515	1.551	-0.301	-0.857
-0.619	-0.762	-0.251	-0.997	-0.425	-0.343	0.075	0.877
0.277	-1.102	0.209	-1.905	-0.240	-0.411	0.218	0.661
0.941	2.226	-0.724	-0.660	-0.358	-1.169	0.893	-0.330
-0.676	0.219	-0.497	1.811	-0.216	-1.345	0.608	-0.428
1.205	1.505	-0.031	0.072	0.828	-1.539	0.526	3.338
0.479	1.800	0.620	0.835	1.775	-0.202	-1.665	0.533
0.717	-0.090	-0.114	2.021	1.730	-0.385	-1.190	-0.043
1.629	0.195	0.880	0.718	-0.563	-0.431	0.796	-0.487
1.320	1.349	-0.277	2.218	-0.610	-0.389	-0.277	0.121
1.682	0.972	1.297	-0.027	-0.247	-0.341	0.207	-0.855
1.134	1.105	-1.106	0.245	-0.565	-0.001	-0.236	-0.033
1.343	0.881	0.189	0.755	-0.047	-0.658	-0.206	0.023
-0.931	1.764	0.012	0.039	-0.018	-0.682	-0.455	-0.036
-0.965	1.843	-0.229	0.185	-0.199	-0.894	-0.678	-0.061
-0.322	0.679	-0.578	0.765	-0.095	-1.529	-0.330	3.554
-0.956	-0.759	0.300	0.256	1.811	-1.319	-0.422	-0.326
-0.623	-0.477	-0.797	0.227	0.027	-0.314	0.486	0.191
-0.467	0.194	-0.539	0.809	-0.771	-0.338	0.503	-0.984
-1.446	0.433	-0.321	0.492	-0.807	0.105	-0.321	-0.942
-0.594	-0.449	0.796	0.994	-0.471	0.149	-0.521	-0.899
0.337	0.053	-1.940	-1.085	-0.532	-0.560	0.251	-0.408
-0.494	1.656	-0.066	0.368	-0.763	-0.648	0.395	-0.857
-0.523	0.687	0.775	-0.179	-0.734	-0.099	-0.215	-0.023
-0.433	0.629	0.714	-0.372	-0.397	-0.817	-0.132	-0.035
-0.099	0.623	-0.101	-0.581	-0.385	-1.642	0.460	2.849
-0.801	0.049	-0.301	1.002	0.134	-0.982	0.053	-1.191
-0.592	-0.144	-0.643	1.140	0.079	-1.175	0.220	-0.652

The high loading scores for four factors are observed in the Table.7 at Panposh downstream, Talcher up-stream, Kamalanga downstream and Pottamundai indicating inorganic pollution risk in the months of July, August and September.

The findings discussed above in Table.7 reveal the fact that any water quality parameter represented by four factors could be used as an indicator for potential contamination of inorganic and organic matter, respectively. In other words, any arbitrary selected parameters from the four factors could be used as a 'marker' variable to detect the level of contamination in River Brahmani. This marker parameter selection might be used as software based technical tool for designing water quality monitoring networks. These marker parameters are revealed on a continuous basis on several selected stations and any anomaly in the calculated values could be evaluated as a potential contamination risk in River Brahmani. To reveal all such Potential of contamination in River water quality, regular full spectrum of water quality parameters could be analysed.

5. Conclusions

The multivariate statistical analysis technique is implemented to analyze large water quality data sets collected from Brahmani River Basin in the four months of monsoon seasons at five gauging stations.

Four factors are found out to be significant according to Eigen value analysis by SPSS in representing the water quality parameters in the Basin. The extracted four factors shows high and low loading values, which shows the correlation between parameters as well as the potential of contamination in the River depending upon the five gauging stations in the River Brahmani.

From the multivariate statistical analysis these factors are believed to represent organic and inorganic contamination in the River Basin. These organic and inorganic contaminations are due to industrial effluents discharge as well as domestic and agricultural pollution and disposal to the river water without any effluent treatment. The multivariate factorial analysis signifies its importance in detecting water pollution of monitoring networks and also provides a useful tool for the decision makers in determining the extent of pollution indicators.

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