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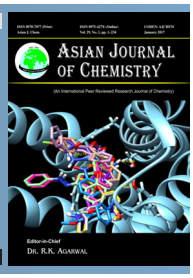

Assessment of Lake Water Quality Using Factor Analysis: A Case Study of North Belgaum City, India†

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The paper presents the assessment of water quality status of three lakes located in the northern part of Belgaum city of Karnataka state, namely, Fort Lake, Kanbargi Lake and Kangrali Lake using factor analysis. Total 15 water quality parameters analyzed from December 2013 to May 2014 were used. The results indicated that in all three lakes six parameters namely, turbidity, BOD, DO, calcium hardness, magnesium hardness and potassium are above the desirable limits as per BIS: 10500-2012. In addition, in Kanabargi Lake, alkalinity and TDS and in Kangrali Lake alkalinity are beyond the desirable limits. Based on the results of factor analysis the significant factors influencing the quality of Fort Lake, Kanbargi Lake and Kangrali Lake are respectively categorized into four, five and four groups explaining 93.34, 100 and 94.41 % of total variances. This shows that the multivariate statistical analysis facilitate in interpreting the large data of complex nature.

Keywords: Water quality, Principal component analysis, Factor analysis, Factor loadings, Belgaum city lakes.

INTRODUCTION

Water is the most precious natural resource essential for sustainability of plant, animal and human life on the earth surface. Recently it is an experienced endangered natural resource due to the impact of climate changes. Hence the preservation of various water bodies such as lakes, rivers and streams with respect to their quality is of utmost requirement as they provide water resources for domestic, industrial and agricultural purposes [1]. Further, the effluents from domestic and industrial sources as well as agricultural discharges become responsible for the degradation of their water quality, in particular the lake water quality. Consequently, the aquatic ecosystem gets hampered and also the lakes experience eutrophication with excess nutrients. Therefore, the regular monitoring of lakes with required number of parameters in relation to water quality is essential for the sustainable conservation of these resources. In this context, many researchers have undertaken the case studies on the assessment of water quality of lakes and rivers in India [2-6] as well as in other countries [1,7-12].

Further, the water quality assessment involves the collection of water samples for a long period of time followed by their analysis for number of parameters. This results into generation of large data set having complex nature making it difficult to interpret. Under such circumstances, the multivariate statistical tools such as principal component analysis (PCA), factor analysis (FA), cluster analysis (CA), discriminant analysis (DA) and multidimensional scaling (MDS) become useful in analyzing the data for meaningful conclusions [1,12]. The successful application of these techniques in various areas such as surface and ground water quality analysis, air quality pattern, soil contamination, nutrient loading in lakes and others studied by many investigators is reported by Yusuf *et al.* [1].

Belgaum city is a district place situated in the north western part of Karnataka. It was receiving continuous monsoon during June to September. However, in the recent years a shift in the rainfall trend associated with reduced rainfall is being experienced. Hence, the lakes present in the city have gained importance to meet the water demand in various parts of the city. In this perspective, three lakes in north part of Belgaum city are considered in the present case study of water quality assessment. The principal component and factor analysis were employed in order to find the inter-relationships between various water quality parameters and to identify the source and its contribution for a particular parameter.

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EXPERIMENTAL

Study area: Belgaum city is situated at 15.87°N latitude and 74.50°E longitude with an elevation of 747.47 m above mean sea level. The annual average rainfall is over 1500 mm. The temperature during the summer season will be between 25 and 40 °C, where as winter will be chilled and pleasant. The area of Belgaum city is 94 km^2 and is divided into 58 wards. As per 2011 census, the population of Belgaum city is 488,292 with a density of 5200/km^2. The main source of water supply to Belgaum city is Malaprabha river. Many lakes are present in and around the city; they are Fort Lake, Kanabargi Lake, Kangrali Lake, B.K. Kangrali Lake, Argan talav, Basavanakudachi Lake, Vadagaon Lake, Angol Lake, Khadarwadi talav and Majagaon Lake. In the present study, Fort Lake, Kanabargi Lake and Kangrali Lake are considered as these are the major lakes located in northern part of Belgaum.

Fort Lake is situated at 15°51'59.69" N latitude and 74°31'34.78" E longitude with an area of 66 acres. The lake is situated at the entrance of Belgaum city and is mainly used for recreational purpose. The Kanabargi Lake is located at 15°53'28.46" N latitude and 74°30'14.47" E longitude. It has an area of 11.84 hectares. It is observed that the local people dispose of solid waste in this lake. The geographical location of Kangrali Lake is at 15°53'46.61"N latitude and 74°30'53.78"E longitude. The surface area of the lake is 28.80 hectares. It is being used by local people for washing clothes, animals and vehicles. The lake is surrounded by fields due to which it also receives agricultural runoff.

Principal component analysis: Principal component analysis (PCA) is a multivariate statistical tool employed to reduce the large number of interrelated variables involved in a phenomena into a set of uncorrelated and orthogonal variables. It works on the principal of linear projection method to reduce the variables. It helps in reducing the dimensions of a problem thereby simplifying the interpretation of data. The new axes are orthogonal, which are the rotation of existing axes to new positions in the space defined by original variables. Further, they represent the directions of maximum variability. The newly formed variables, called principal components (PCs) are expressed as linear combinations of the original set of variables involving Eigen vectors [1,12]. The principal components are calculated in a such a way that the first principal component explains the largest proportion of variability within the original data followed by the second principal component explaining next largest proportion of the variability that has not been explained by the first principal component [13] and so on. The varimax rotation is most suitable in rotating the principal components for a better relationship between the principal components and the original variables. Varimax rotation ensures that each principal component is correlated with only one component and has a near zero association with the other components [14]. The new variables called varimax factors (VFs) are obtained, the principal components having Eigen value greater than 1 are used in the principal component varimax rotation [14]. The factor loadings after rotation indicate how much each variable contributes to that particular principal component and to what extent one variable is similar to the other. The factor loadings greater than 0.75 are considered as "strong"; 0.75-0.50 as "moderate" and 0.49-0.30 as "weak" [15]. The higher factor loading of a particular variable implies larger contribution of the variable towards a particular principal component.

RESULTS AND DISCUSSION

Water quality parameters: Table-1 presents the water quality parameters of the three lakes indicating the minimum and maximum values, average value, standard deviation and standard error along with the desirable limits as prescribed by BIS:10500-2012 [16]. The mean values of each of the parameters with the standard deviation and standard error in the form of error bars are presented in Fig. 1. Based on the results the following results are observed.

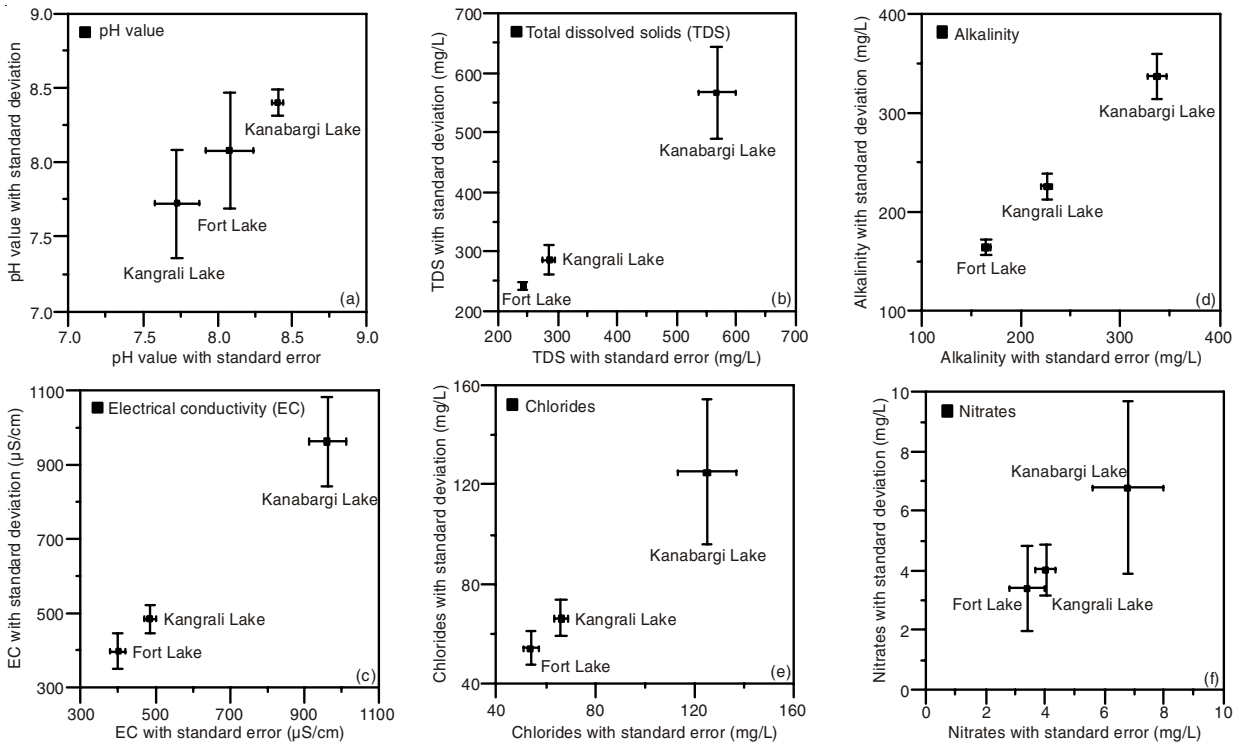
In Fort Lake, the parameters such as turbidity, BOD, DO, calcium hardness, magnesium hardness and potassium are above the desirable limits as prescribed by BIS: 10500-2012 [16]. However, the other parameters like pH, total dissolved solids, alkalinity, total hardness, sodium, phosphorous, electrical conductivity, chlorides and nitrates are well within the desirable limit. Kanabargi Lake water highlights that the parameters namely turbidity, BOD, DO, calcium hardness, magnesium hardness, potassium, alkalinity and total dissolved solids are exceeding the desirable limits prescribed by BIS: 10500-2012 [16]. On the other hand, the parameters such as pH, total hardness, sodium, phosphorous, electrical conductivity, chlorides and nitrates are within the desirable limit. Similarly, in Kangrali Lake water, turbidity, BOD, DO, calcium hardness, magnesium hardness, potassium and alkalinity are crossing the desirable limit as prescribed by the BIS: 10500-2012 [16]. On the contrary pH, total dissolved solids, magnesium hardness, sodium, phosphorous, electrical conductivity, chlorides and nitrates are well within the desirable limit. The above results indicate that in all the three lakes turbidity, BOD, DO, calcium hardness, magnesium hardness and potassium are beyond the prescribed desired limits. The higher values of calcium and magnesium hardness may be due to the inflow of ground water that is flowing through red soil. The soil type in Belgaum is black and red, which is rich in calcium and magnesium. Also, the washing of clothes by the local people might have contributed to the enhanced calcium hardness. The larger value of potassium is due to the presence of lateritic rocks. Further, the lower organic load into lake and exposure of the lake to atmospheric oxygen has influenced the DO and BOD contents and the presence of suspended particles resulted into greater turbidity level.

Principal component analysis: Principal component analysis (PCA) was applied to the data sets (15 parameters) separately for the three different lakes in order to extract the most significant principal components (PCs) and to eliminate the variables having less significance. The principal components are extracted using a criterion of Eigen values greater than 1 that explain the sources of variance in the data. The SySTAT software was used to carry out principal component analysis in this study. From the analysis, for the Fort Lake and Kangrali Lake, each four principal components having total variance of 93.34 % and 94.41 % while five principal components for Kanabargi Lake with 100 % of total variance in respective of water quality data sets were obtained.

TABLE-1
WATER QUALITY PARAMETERS OF THREE LAKES DURING DECEMBER 2013-MAY 2014

Parameters		pH	Total dissolved solids (mg/L)	Electric conductivity (µS/cm)	Alkalinity (mg/L)	Chlorides (mg/L)	Total hardness (mg/L)	Calcium hardness (mg/L)
Fort Lake	Minimum	7.49	233.3	302.5	154	45.67	121.5	75
	Maximum	8.49	248.34	440	175	61.553	135	97
	Average	8.08	241.58	398.33	164.37	54.02	128.5	82.11
	Standard deviation	0.39	5.93	49.3131	8.41	7	4.59	8.31
	Standard error	0.161	2.421	20.132	3.431	2.856	1.875	3.394
Kanabargi Lake	Minimum	8.29	493.33	815	306	96.31	215	130
	Maximum	8.53	680	1133.33	363.34	177.04	270	170
	Average	8.41	567.78	962.06	336.69	125.17	237.3	154.17
	Standard deviation	0.09	76.64	120.43	22.85	29.37	25.27	15.34
	Standard error	0.038	31.29	49.164	9.328	11.991	10.32	6.261
Kangrali Lake	Minimum	7.41	260	433.34	206	55.602	114.7	86
	Maximum	8.36	328	546.67	240.8	76.78	136.6	118
	Average	7.73	285.78	484.34	225.95	66.1	130.1	103.11
	Standard deviation	0.36	24.56	38.76	13.3	7.22	8	11.99
	Standard error	0.148	10.025	15.823	5.428	2.946	3.268	4.895
BIS limit		6.5 - 8.5	500	2000	200	250	300	75

Parameters		Magnesium hardness (mg/L)	Nitrates (mg/L)	Potassium (mg/L)	Phosphorous (mg/L)	DO (mg/L)	BOD (mg/L)	Sodium (mg/L)	Turbidity (NTU)
Fort Lake	Minimum	33.62	2	1	0.525	6.77	1.5	11.12	2.22
	Maximum	51.35	5.675	4	1.445	8.64	5.62	15	6.675
	Average	42.03	3.4	2.17	0.9	7.62	3.1	13.41	5.02
	Standard deviation	7.42	1.42	1.17	0.31	0.75	1.62	1.45	1.62
	Standard error	3.029	0.579	0.477	0.127	0.306	0.66	0.59	0.659
Kanabargi Lake	Minimum	65	4	0	0.6	6.2	1.87	33.67	4
	Maximum	103.34	12.133	4	1.27	8.7	3.14	55	20.8
	Average	85.91	6.79	1.83	1.08	7.39	2.56	42.28	14.99
	Standard deviation	16.95	2.93	1.47	0.26	0.9	0.55	6.99	5.74
	Standard error	6.919	1.196	0.601	0.107	0.369	0.223	2.855	2.345
Kangrali Lake	Minimum	17.34	2.76	2	0.6	6.4	3	13.67	3.8
	Maximum	37.33	5.2	5.34	1.27	8.24	7.67	20	8.64
	Average	27	4.02	0.84	3.83	7.05	5.7	16.72	6.51
	Standard deviation	7.06	0.86	0.24	1.24	0.67	1.58	2.64	1.56
	Standard error	2.883	0.349	0.508	0.0965	0.275	0.64	1.079	0.637
BIS limit		30	45	1	5	4	3	250	1



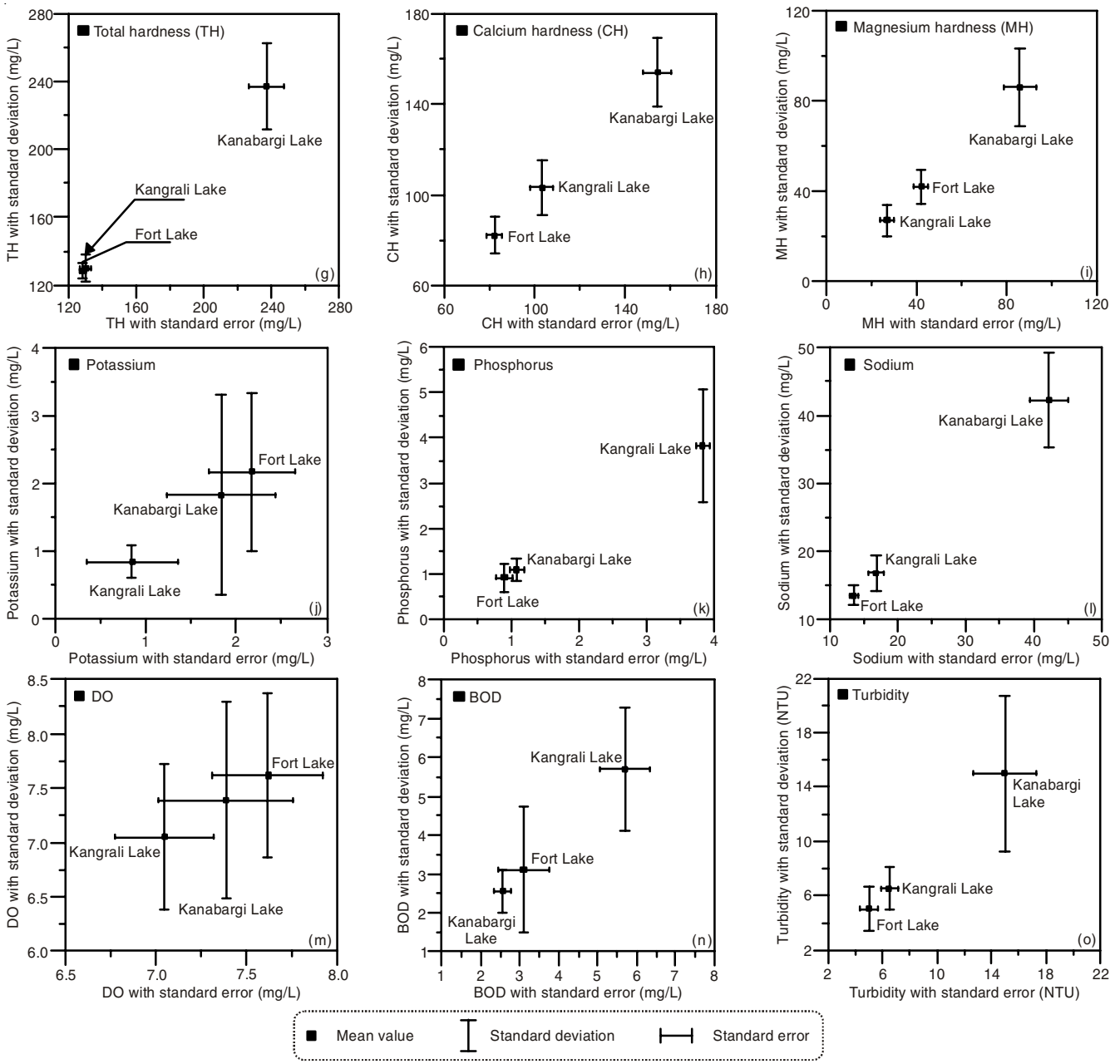


Fig. 1. Error bars showing the mean values, standard deviation and standard of different parameters

Fort Lake: The results of principal component analysis for the data set of Fort Lake yielded four principal components with Eigen values > 1, explaining 93.341 % of the total variance in respective of water quality parameters. Table-2 presents the four principal components having Eigen values greater than 1 along with percentage variance of each principal component, cumulative percentage of variance and component loadings for water quality parameters for Fort Lake. The corresponding equal numbers of Varimax rotated principal components (VFs) were obtained through factor analysis (FA) performed on the principal components. Corresponding VFs, variable loadings and explained variances for the Fort Lake results are presented in Table-3.

The Varimax rotated factors obtained through factor analysis for the data set pertaining to Fort Lake shown in Table-3 indicate that the factor VF1, explaining 26.46 % of total variance, has strong positive loading on pH, electrical conductivity (EC) and total hardness while strong negative loading on turbidity. This factor indicates the variability of water quality due to physio-chemical sources. Factor VF2 with 25.12 % of total variance, has strong positive loading on alkalinity, phosphorous and sodium while strong negative loading on magnesium hardness. This factor represents organic pollution from domestic waste. Similarly, VF3 explaining 22.94 % of total variance has strong positive loading on chlorides and BOD has strong negative loading on calcium hardness. It also has moderate positive loading on nitrates. Further, the factor VF4 explaining 18.81 % of total variances, has high strong positive loading on DO and strong negative loading on TDS and moderate positive loading on potassium.

Kanabargi Lake: From the principal component analysis applied to Kanabargi Lake water quality parameters, five

TABLE-2
EXTRACTION VALUES OF THE TOTAL VARIANCE USING PRINCIPAL COMPONENT ANALYSIS FOR WATER QUALITY PARAMETERS OF FORT LAKE

Component	Initial eigen values			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)
1	5.944	39.630	39.630	5.944	39.630	39.630	3.969	26.461	26.461
2	3.286	21.907	61.537	3.286	21.907	61.537	3.769	25.124	51.585
3	2.930	19.532	81.069	2.930	19.532	81.069	3.441	22.938	74.523
4	1.841	12.272	93.341	1.841	12.272	93.341	2.823	18.818	93.341
5	0.999	6.659	100.000						
6	4.397×10^{-16}	2.932×10^{-15}	100.000						
7	3.544×10^{-16}	2.362×10^{-15}	100.000						
8	2.840×10^{-16}	1.894×10^{-15}	100.000						
9	1.708×10^{-16}	1.139×10^{-15}	100.000						
10	3.468×10^{-17}	2.312×10^{-16}	100.000						
11	-1.30×10^{-16}	-8.68×10^{-16}	100.000						
12	-1.44×10^{-16}	-9.59×10^{-16}	100.000						
13	-2.63×10^{-16}	-1.75×10^{-15}	100.000						
14	-4.49×10^{-16}	-2.99×10^{-15}	100.000						
15	-2.22×10^{-15}	-1.48×10^{-14}	100.000						

TABLE-3
FACTOR LOADING MATRIX AND TOTAL VARIANCE EXPLAINED FOR FORT LAKE

Parameters	VF1	VF2	VF3	VF4
Four significant principal components				
pH	**0.907**	-3.57×10^{-2}	4.348×10^{-2}	0.163
TDS (mg/L)	-0.142	0.210	2.766×10^{-2}	**-0.949**
EC (mg/L)	**0.907**	0.205	5.079×10^{-2}	-0.363
Alkalinity (mg/L)	0.171	**0.954**	9.767×10^{-2}	0.184
Chlorides (mg/L)	0.164	0.150	**0.971**	-8.01×10^{-2}
Total hardness (mg/L)	**0.863**	1.040×10^{-2}	-0.335	1.972×10^{-2}
Calcium hardness (mg/L)	0.286	0.225	**-0.858**	-0.317
Magnesium hardness (mg/L)	0.250	**-0.937**	0.144	0.106
Nitrates (mg/L)	-0.415	0.429	***0.624***	0.157
Potassium (mg/L)	-0.468	0.344	0.351	***0.697***
Phosphorous (mg/L)	0.270	**0.816**	0.402	0.164
DO (mg/L)	4.709×10^{-2}	0.164	0.102	**0.934**
BOD (mg/L)	-0.365	0.390	**0.778**	5.488×10^{-2}
Sodium (mg/L)	-0.320	**0.760**	0.421	-0.351
Turbidity (NTU)	**-0.811**	0.309	0.383	-0.275
Eigen value	3.969	3.769	3.441	2.823
Total variance (%)	26.461	25.124	22.938	18.818
Cumulative (%)	26.461	51.585	74.523	93.341

Note: Bold indicates strong loadings and italic bold values indicate moderate loadings.

principal components with Eigen values > 1, explaining 100 % of the total variances were obtained. The principal components with their respective variance along with cumulative percentage of variance and component loadings are furnished in Table-4. Table-5 presents the corresponding Varimax rotated principal components (VFs) obtained by factor analysis (FA) performed on the principal components for the Kanabargi Lake.

Among the five VFs as given in Table-5 for the data set pertaining to Kanabargi Lake, the first factor VF1, explaining 30.429 % of total variance, has strong positive loading on TDS, EC and chlorides while strong negative loading on calcium hardness and phosphorous. It also has moderate negative loading on total hardness. This variability may be because of physico-chemical source. Similarly, VF2 with 22.479 % of total variance, on one hand has strong positive loading on potassium and sodium and on the other hand, moderate loading on turbidity (positive) and total hardness (negative), indicating organic pollution as a result of domestic waste disposal in the locality. Further, VF3 explaining 17.437 % of total variance, has strong positive loading on alkalinity and magnesium hardness and strong negative loading on pH. Next, factor VF4, having total variance of 16.171 % has high strong positive loading on nitrate and strong negative loading on BOD along with moderate positive loading on magnesium hardness. Lastly, factor 5 (VF5) explaining 13.485 % of total variance, has high positive loading on DO while moderate on pH.

Kangrali Lake: Four principal components were obtained for the Kangrali Lake after principal component analysis applied to water quality parameters, explaining 94.41 % of the total variances. Table-6 presents the principal components with their respective variance along with cumulative percentage of variance and component loadings. The corresponding four Varimax rotated principal components (VFs) obtained by factor analysis (FA) performed on the principal components for the

TABLE-4
EXTRACTION VALUES OF THE TOTAL VARIANCE USING PRINCIPAL COMPONENT ANALYSIS FOR WATER QUALITY PARAMETERS FOR KANABARGI LAKE

Component	Initial eigen values			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)
1	5.950	39.670	39.670	5.950	39.670	39.670	4.564	30.429	30.429
2	3.248	21.655	61.325	3.248	21.655	61.325	3.372	22.479	52.908
3	2.697	17.979	79.304	2.697	17.979	79.304	2.615	17.437	70.344
4	2.030	13.532	92.836	2.030	13.532	92.836	2.426	16.171	86.515
5	1.075	7.164	100.000	1.075	7.164	100.000	2.023	13.485	100.000
6	9.432×10^{-16}	6.288×10^{-15}	100.000						
7	4.501×10^{-16}	3.001×10^{-15}	100.000						
8	1.055×10^{-16}	7.032×10^{-16}	100.000						
9	8.969×10^{-17}	5.979×10^{-16}	100.000						
10	-6.96×10^{-18}	-4.64×10^{-17}	100.000						
11	-6.75×10^{-17}	-4.50×10^{-16}	100.000						
12	-1.56×10^{-16}	-1.04×10^{-15}	100.000						
13	-2.76×10^{-16}	-1.84×10^{-15}	100.000						
14	-3.71×10^{-16}	-2.47×10^{-15}	100.000						
15	-7.22×10^{-16}	-4.81×10^{-15}	100.000						

TABLE-5
FACTOR LOADING MATRIX AND TOTAL VARIANCE EXPLAINED FOR KANABARGI LAKE

Parameters	VF1	VF2	VF3	VF4	VF5
	Five significant principal components				
pH	-0.125	3.535E-02	**-0.721**	2.659E-02	***0.680***
TDS (mg/L)	**0.943**	0.159	0.229	0.182	-1.26×10^{-2}
EC (mg/L)	**0.889**	-0.134	0.412	0.142	4.292×10^{-2}
Alkalinity (mg/L)	0.391	0.250	**0.863**	-0.155	-0.123
Chlorides (mg/L)	**0.897**	-0.241	-2.62×10^{-2}	-3.60×10^{-2}	-0.370
Total hardness (mg/L)	***-0.608***	***-0.522***	0.428	0.407	-9.39×10^{-2}
Calcium hardness (mg/L)	**-0.788**	-0.430	-1.67×10^{-2}	0.191	0.397
Magnesium hardness (mg/L)	5.455×10^{-2}	-0.295	**0.764**	***0.520***	-0.236
Nitrates (mg/L)	9.894×10^{-2}	1.861×10^{-2}	-9.82×10^{-2}	**0.970**	-0.199
Potassium (mg/L)	0.280	**0.957**	-4.80×10^{-2}	5.727×10^{-2}	-1.89×10^{-2}
Phosphorous (mg/L)	**-0.799**	-0.457	-0.128	-7.16×10^{-2}	-0.363
DO (mg/L)	-7.47×10^{-2}	-0.221	-0.246	-6.57×10^{-2}	**0.939**
BOD (mg/L)	3.868×10^{-2}	-0.308	-0.195	**-0.886**	-0.286
Sodium (mg/L)	-0.229	**0.957**	-1.37×10^{-2}	9.940×10^{-2}	-0.151
Turbidity (NTU)	0.367	***0.693***	0.484	0.354	-0.162
Eigen value	4.564	3.372	2.615	2.426	2.023
Total variance (%)	30.429	22.479	17.437	16.171	13.485
Cumulative (%)	30.429	52.908	70.344	86.515	100

Note: Bold indicates strong loadings and italic bold values indicate moderate loadings.

TABLE-6
EXTRACTION VALUES OF THE TOTAL VARIANCE USING PRINCIPAL COMPONENT ANALYSIS FOR WATER QUALITY PARAMETERS FOR KANGRALI LAKE

Component	Initial eigen values			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)
1	7.891	52.607	52.607	7.891	52.607	52.607	5.574	37.160	37.160
2	2.825	18.831	71.439	2.825	18.831	71.439	4.202	28.011	65.171
3	2.264	15.092	86.531	2.264	15.092	86.531	2.303	15.351	80.522
4	1.182	7.882	94.412	1.182	7.882	94.412	2.084	13.890	94.412
5	0.838	5.588	100.000						
6	2.046×10^{-15}	1.364×10^{-14}	100.000						
7	6.320×10^{-16}	4.213×10^{-15}	100.000						
8	4.469×10^{-16}	2.979×10^{-15}	100.000						
9	3.174×10^{-16}	2.116×10^{-15}	100.000						
10	2.557×10^{-16}	1.705×10^{-15}	100.000						
11	1.529×10^{-16}	1.019×10^{-15}	100.000						
12	1.194×10^{-16}	7.960×10^{-16}	100.000						
13	9.470×10^{-18}	6.313×10^{-17}	100.000						
14	-4.82×10^{-17}	-3.21×10^{-16}	100.000						
15	-4.49×10^{-16}	-2.99×10^{-15}	100.000						

Kangrali Lake are given in Table-7. Amongst four VFs, VF1, explaining 37.16 % of total variance, has strong positive loading on TDS, EC, phosphorous and sodium and strong negative loading on total hardness. Also VF1 has moderate negative loading on calcium hardness. It is due to variations in physico-chemical source. The second factor VF2 explaining 28.01 % of total variance, has strong positive loading on magnesium hardness and turbidity while moderate positive loading on alkalinity and BOD and moderate negative loading on pH, calcium hardness and DO caused by domestic waste disposal. Similarly, VF3 explaining 15.35 % of total variance, has strong positive loading on nitrate and has moderate positive loading on pH and moderate negative loading on sodium and BOD. Further, VF4 with 13.88 % of total variances, has strong positive loading on potassium and strong negative loading on chlorides.

From the factor analysis, the significant factors and their respective associated water quality parameters influencing the water quality for the three lakes are summarized in Table-8. It helps in identifying most significant parameter affecting the water quality.

Conclusions

The water quality analysis of three lakes in Belgaum City is carried out using principal component analysis and factor analysis considering 15 water quality parameters measured during December 2013 to May 2014. The following conclusions can be drawn from the study:

• In all three lakes: turbidity, BOD, DO, calcium hardness, magnesium hardness and potassium are found to be above the desirable limits as prescribed by BIS: 10500-2012 [16]. Also, alkalinity and total dissolved solids contents are beyond the limits in Kanabargi Lake while Kangrali Lake has higher value of alkalinity.

• The principal component analysis applied to the data sets of three different lakes: Fort Lake, Kanabargi Lake and Kangrali Lake resulted into respective four, five and four

TABLE-7
FACTOR LOADING MATRIX AND TOTAL VARIANCE EXPLAINED FOR KANGRALI LAKE

Parameters	VF1	VF2	VF3	VF4
Four significant principal components				
pH	-0.463	***-0.613***	***0.534***	0.122
TDS (mg/L)	**0.867**	0.421	-0.112	0.183
EC (mg/L)	**0.879**	0.176	-0.229	-0.264
Alkalinity (mg/L)	0.508	***0.616***	0.406	0.313
Chlorides (mg/L)	0.423	7.361×10^{-2}	-3.54×10^{-2}	**-0.897**
Total hardness (mg/L)	**-0.953**	-0.155	-3.60×10^{-2}	8.612×10^{-2}
Calcium hardness (mg/L)	***-0.700***	***-0.674***	-1.50×10^{-2}	-5.97×10^{-2}
Magnesium hardness (mg/L)	0.107	**0.968**	-1.54×10^{-2}	0.199
Nitrates (mg/L)	-0.154	-2.58×10^{-2}	**0.938**	0.287
Potassium (mg/L)	0.276	6.646×10^{-2}	0.357	**0.880**
Phosphorous (mg/L)	**0.969**	3.703×10^{-2}	8.027×10^{-3}	-6.39×10^{-2}
DO (mg/L)	-0.572	***-0.742***	4.709×10^{-3}	0.318
BOD (mg/L)	-4.20×10^{-2}	***0.615***	***-0.630***	-6.54×10^{-2}
Sodium (mg/L)	**0.774**	0.204	***-0.542***	0.141
Turbidity (NTU)	0.146	**0.917**	-0.292	-0.156
Eigen value	5.574	4.202	2.303	2.084
Total variance (%)	37.16	28.01	15.35	13.88
Cumulative (%)	37.16	65.17	80.52	94.41

Note: Bold indicates strong loadings and italic bold values indicate moderate loadings.

TABLE-8
SIGNIFICANT FACTORS ALONG WITH WATER QUALITY PARAMETERS

	Lakes	Factors and strong water quality parameters				
		VF1	VF2	VF3	VF4	VF5
Fort Lake	Eigen value	3.969	3.769	3.441	2.823	–
	Total variance (%)	26.461	25.124	22.938	18.818	–
	Water quality parameters	pH, electrical conductivity, total hardness, turbidity	Alkalinity, magnesium hardness, phosphorous, sodium	Chlorides, calcium hardness, BOD	Total dissolved solid, DO	–
Kanabargi Lake	Eigen value	4.564	3.372	2.615	2.426	2.023
	Total variance (%)	30.429	22.479	17.437	16.171	13.485
	Water quality parameters	Total dissolved solids, electrical conductivity, chlorides, calcium hardness, phosphorous	Potassium, sodium	pH, alkalinity, magnesium hardness	Nitrates, BOD	DO
Kangrali Lake	Eigen value	5.574	4.202	2.303	2.084	–
	Total variance (%)	37.16	28.01	15.35	13.88	–
	Water quality parameters	Total dissolved solids, electrical conductivity, total hardness, phosphorous, sodium	Magnesium hardness, turbidity	Nitrate	Chloride, potassium	–

principal components explaining total variance of 93.34 %, 100 % and 94.41 % in respective of water quality parameters.

• It can be seen that the results of principal component analysis and physico-chemical analysis depict nearly similar parameters, which affect the water quality of all the three lakes. Thus, the study illustrates the usefulness of multivariate statistical techniques for analysis and interpretation of complex data sets in water quality assessment, identifying the pollution sources/ factors and understanding the variation in water quality for effective lake water quality management.

REFERENCES

1. K.A. Yusuf, S.O. Oluwole, I.O. Abdusalam and A.O. Majolagbe, *J. Environ.*, **2**, 94 (2013).
2. L.P. Dalal, S.P. Kalbende and R.S. Nisal, *Int. J. Sci. Engg. Res.*, **4**, 1 (2013).
3. H. Pathak and D. Pathak, *Environ. Anal. Toxicol.*, **2**, 1 (2012).
4. O. Singh, S.P. Rai, V. Kumar, M.K. Sharma and V.K. Choubey, in eds.: M. Sengupta and R. Dalwani, Water Quality and Eutrophication Status of Some Lakes of Western Himalayan Region, Proceedings of Taal 2007. The 12th World Lake Conference, pp. 286-291 (2008).
5. B.Y. Vyankatesh, A.B. Bhosle, P.R. Shaikh and S.R. Gaikwad, *Int. J. Innov. Appl. Stud.*, **3**, 504 (2013).
6. J. Zaidi, S. Ganesh and A. Pal, *Int. J. Curr. Res*., **3**, 27 (2011).
7. K.A. Alfred, O.D. Godfred, K.A. Elikem and S.-A. Yaw, *Int. J. Chem.*, **3**, 32 (2011).
8. S. Apeh and O.E. Ekenta, *Trends Eng. Appl. Sci.*, **3**, 904 (2012).
9. A.R. Pradhananga, *Tech. Math.*, **9**, 141 (2012).
10. V. Raicevic, M. Bozic, Z. Rudic, B. Lalevic and D. Kikovic, *Afr. J. Biotechnol.*, **10**, 1739 (2011).
11. A.-O. Richard, D.W. Edward and B.K. Bridgette, *Afr. J. Environ. Sci. Technol.*, **5**, 1093 (2011).
12. S. Shrestha and F. Kazama, *Environ. Model. Softw.*, **22**, 464 (2007).
13. I.T. Jolliffe, Principal Component Analysis. New York, Springer-Verlag (2002).
14. D. Dominick, H. Juahir, M.T. Latif, S.M. Zain and A.Z. Aris, *Atmos. Environ.*, **60**, 172 (2012).
15. C.W. Liu, K.H. Lin and Y.M. Kuo, *Sci. Total Environ.*, **313**, 77 (2003).
16. Indian Standard Drinking Water – Specification, IS:10500-2012 (2012).