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Study on Environmental Impact of Chemical Pollutants & Interpretation of Characteristics Using Statistical Technique in Water Quality of Keenjhar Lake Located In Sindh Pakistan

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Abstract

Concerns about the water quality in Keenjhar Lake, a fresh water lake, located in province of Sindh, Pakistan have been expressed recently due to the natural and anthropogenic pollution. In order to understand the underlying physical and chemical processes in Keenjhar Lake, the present paper determines quality indicators for periodical monitoring of the lake water quality factors identified by using principal components analysis on 17 Physico-chemical parameters including five heavy metal ions representing eight different locations in the year 2013 in and around the lake. Metals, in general, showed a moderate to high degree of correlation among them. Principal component analysis and factor analysis have been applied to explore the source of the water quality parameters as the result of various anthropogenic activities.

Keywords: Physico-chmical parameters, Heavy metals, principal component analysis, Keenjhar Lake

1. Introduction

Current state of the world's lakes is indeed alarming and people around the world will have to make concerted effort to reverse the trend toward degradation. Many fresh water reservoirs have been degraded and lost their significant importance due to a number of effluents discharge and anthropogenic activities into aquatic environment along with draught conditions for the last several years [1]. Increase in Pollutants resulting from industrial waste, urban run-off, boating activities, agricultural fungicides, domestic garbage, dumps, anthropogenic activities and mining operations have largely affected aquatic ecosystems [2-4]. Hydrographic conditions of aquatic ecosystem and seasonal variations of physico- chemical properties affect the quality of lakes water [5-10].

The Indus is the longest and the most important river of Pakistan which eventually falls into Arabian Sea after distributing its water to some lakes adjacent to its bank, like Haleji and Keenjhar lakes [11]. Lakes are large bodies (i.e., greater than 20 acres) of inland water. Most of the drinking water, as well as water used for irrigation, industry and hydropower come from freshwater lakes and reservoirs in Pakistan including Keenjhar Lake. The lake, however, has steadily declined in both productivity and its freshwater resources chiefly on account of chemical pollution, over fishing and eutrophication.

Among the main causes, the chemical waste from industries and raw sewage from city along the river are most prominent. The lake, therefore, is facing serious environmental degradation. In order to make improvement in water quality of the lakes, a better understanding was needed to obtain the fundamental information related to drinking water about sources of contaminations and to check the suitability of water quality for its intended use. This study was specifically designed to assess physico-chemical parameters and heavy metals ions concentration of the Keenjhar lake by using statistical technique.

The application of different statistical techniques, such as correlation analysis, principal component analysis (PCA), factor analysis (FA) assists in the interpretation of complex data matrices for a better understanding of water quality and ecological characteristics of a study area. These techniques provide the identification of possible sources that affect environmental systems of water and offer a valuable tool for reliable management of water resources as well as rapid solution to pollution issues [12-14].
Additionally, these statistical techniques have also been widely adopted to analyze and evaluate surface and freshwater water quality, and are useful to verify temporal and spatial variations caused by natural and anthropogenic factors linked to seasonality [15].

1.1. *Background*
Keeenjhar Lake is the major source of supply of drinking water for 200 million people of Karachi metropolitan city and around One hundred thousand people of Thatta and surrounding area are dependent on this fresh water lake and a total of 800 fishing crafts are operating in the area. The lake was declared wildlife sanctuary in 1977 under the Sindh wild life protection ordinance, 1972. It has also designated as Ramsar site in 1976. Keenjhar Lake supports a rich biological diversity situated along Indus flyway zone. Also it is important for breeding & wintering area for water fowl and migratory birds. Additionally the lake is heavily used for recreation, in spite of its algal productivity [16]. It is located in Thatta District, Sindh, Pakistan, about 122 kilometres from Karachi and 20 km North and North – East of Thatta town between the longitude of 68^0.03´E and 69^oNE and latitude 24 and 25^oN.
The Lake is fed by the Kalri Baghar canal originating from Kotri Barrage that enters at the northwest corners, and by many small seasonal streams entering on the western and northern shores. The only outlet is through the Jam branch canal at the southeast corner of the Lake [16].

1.2. *Physical setting*

Surface Area	9842 Ha	Storage Capacity	7.2 million acre feet
Usable Capacity	0.38 million acre feet	Average Depth	9 km
Length of Embankments	31 Km	Max Height of Embankments	9 km
Original life Expectancy	132 years	Reduced life after Silting	87 years
Main water supply Source	KB Feeder (Upper)		
Location	68^0.03´E and 69^oNE and latitude 24 and 25^oN	Outlet	KB Feeder (Lower) & KDA Canal

2. Materials and methods

2.1. Water Sampling

All sampling techniques and laboratory analytical methods were performed in accordance with procedures in Standard Methods for the Examination of water and waste water [17].
Profile occurs at one site of the lake and is positioned over the deepest part of the lake. Profile measurements of physical parameters are taken at one meter intervals from the surface to the bottom lake. Water samples for chemical analysis are collected from one meter below the water surface and 1-2 meter above the lake bottom.
The lake water samples were collected in acid washed plastic container to avoid unpredictable changes in characteristics as per standard procedure [17]. In all sixteen (16) samples were collected from eight (08) sampling points at two different depths (i.e. one meter below the water surface and 1-2 meter above the lake bottom).

To assess the potential source of Keenjhar lake pollution, eight stations were selected. The location map of Keenjhar Lake is shown in Figure 1.

2.2. Sampling Points

- Inlet of the Lake ---------(S1)
- West bank upstream of the lake---(S2)
- Near recreation point -------(S3)
- Midpoint of Lake-------(S4)
- Mid of the east Bank-------(S5)
- Near west bank downstream of Lake----(S6)
- Helaya station: the main boat basin. ---------(S7)
- Outlet of the Lake.-----(S8)

Figure 1: Location map of Keenjhar Lake

2.3. Analytical Instruments

The pH , EC and TDS were measured by using multiparameter ion analyzer (HANNA Instrument). Na^+ and K^+ were measured by using Flame photometer and rest of major cations and heavy metals were measured by using atomic absorption spectrophotometer (Thermo iCE3500-AAS). Anions were analyzed by ion chromatography (Metrohm 761Compact IC with suppressed module, equipped with an anion-separator column (Dual 2).

3. Results and discussion

3.1. Physico-Chemical and heavy metals Analysis

The water samples were collected from upstream to outlet Khumbo station (South), to examine the source of contamination on water quality of Keeenjhar Lake. When sampling was carried out at upstream (Feed point to Lake Keenjhar), the chemical analysis indicated high result with respect to TDS (Total dissolved solid) and EC(Electrical conductivity). In pre-monsoon, the total dissolved solids in water at inlet limit of 524 mg/L. Electrical conductivity was higher in all sampling points. In heavy metals only Fe showed higher values in few sampling points. Whereas other parameters including heavy metals were in the safe limit as recommended by WHO. However, after inlet downstream the results of chemical analysis show a declining in TDS as well as in the concentration of other parameters and conforms to the standards prescribed by WHO. In post- monsoon, almost similar trends were observed but in lower concentrations (Table 1 and Table 2).

Table 1: Physico-chemical and Heavy metals data of Keenjhar Lake (Pre-Monsoon)

Parameters/ Stations	S1	S2	S3	S4	S5	S6	S7	S8	WHO
pH	8.12	8.24	8.47	7.61	8.35	8.2	8.35	8.32	6.5-8.5
EC	871	628	561	567	547	565	569	561	500
Na	82.73	37.97	38.94	43.01	49.27	41.5	40.39	43.93	200
K	4.74	2.40	2.88	3.06	3.56	2.95	2.81	3.01	12
Ca	17.48	8.07	8.01	10.02	9.11	7.64	7.85	7.23	75
Mg	17.33	8.8	9.46	9.43	11.34	9.83	9.8	10.05	30
Cl	85	89	80	67	65	72	75	73	250
CO_3	22.85	11.12	11.55	13.10	13.55	11.60	11.70	11.50	250
SO_4	163	105	146	94	90	98	90	107	200
NO_3	0.8	0.6	1.1	2.4	0.9	1.12	0.9	1.2	50
TURB	62.1	1.73	2.68	2.08	1.77	1.54	1.72	1.33	5
TDS	524	378	337	340	328	334	335	336	500
Cr	0.0015	0.0061	0.0013	0.0075	0.0052	0.0038	0.0045	0.0048	0.05
Co	0.0002	0.0002	0.0002	0.0001	0.0001	0.0003	0.0003	0.0003	0.002
Ni	0.0026	0.0031	0.0036	0.0049	0.0067	0.007	0.0075	0.006	0.02
Fe	0.2103	0.1596	0.1611	0.1557	0.1032	0.3432	0.3684	0.2735	0.3
Zn	0.0333	0.0185	0.0366	0.0317	0.0435	0.0519	0.0332	0.0529	3

Unit: Turb = NTU, pH = SU, EC = μS/cm , Ionic Conc. = mg/l, TDS = mh/l, Metal ion conc. = mg/l

Table 2: Physico-chemical and Heavy metals data of Keenjhar Lake (Post-Monsoon)

Parameters/Stations	S1	S2	S3	S4	S5	S6	S7	S8	WHO
pH	7.61	7.83	8.02	7.35	7.93	7.79	7.93	7.89	6.5-8.5
EC	827	597	533	539	520	537	541	533	500
Na	78.59	36.10	36.99	40.85	46.81	39.43	38.37	41.7	200
K	4.59	2.33	2.79	2.97	3.45	2.86	2.73	2.92	12
Ca	16.96	7.83	7.77	9.72	8.84	7.41	7.61	7.01	75
Mg	16.81	8.36	9.18	9.15	10.99	9.54	9.5	9.75	30
Cl	82.45	86.3	77.6	64.99	63.05	69.84	72.75	70.81	250
CO_3	21.94	10.68	11.09	12.58	13	11.14	11.23	11.04	250
SO_4	156.5	100	140.16	90.24	86.4	94.08	86.4	102.7	200
NO_3	0.77	0.58	1.05	2.3	0.86	1.08	0.86	1.15	50
TURB	59.6	1.66	2.57	1.99	1.69	1.48	1.65	1.28	5
TDS	503	363	323	326	315	321	322	322.5	500
Cr	0.0014	0.0059	0.0012	0.007	0.0049	0.0032	0.0041	0.0043	0.05
Co	0.0001	0.0001	0.0001	0.001	0.0001	0.0002	0.0002	0.0002	0.002
Ni	0.0019	0.0028	0.0021	0.004	0.0059	0.0067	0.0064	0.005	0.02
Fe	0.200	0.148	0.1378	0.1430	0.09	0.3141	0.315	0.2130	0.3
Zn	0.0278	0.0135	0.0257	0.0282	0.0389	0.0420	0.0435	0.0489	3

3.2. Descriptive Statistics

Table 3 and Table 4 present minimum, maximum, mean and standard deviation of Physico-chemical and heavy metals under study in pre and post-monsoon. It is clear that EC and Turbidity (Turb) are the dominant parameters with high mean concentration of 608.6 μS/cm, 9.37 NTU in pre-monsoon and 578.37 μS/cm, 8.99 NTU in post-monsoon respectively. This showed that, these variables play important role in measuring pollution. The mean value of pH is 8.2 in pre-monsoon and 7.8 in post monsoon, indicating that the water samples are almost neutral to sub-alkaline in natural.

Table 3: Descriptive Statistics of physico-chemical and heavy metals of Keenjhar Lake (Pre-Monsoon)

	N	Minimum	Maximum	Mean	Std.Deviation
pH	8	7.6100	8.4700	8.207500	.2640211
EC	8	547.0000	871.0000	608.625000	108.7302527
Na	8	37.97	82.7300	47.217500	14.7706221
K	8	2.4000	4.7400	3.176250	.7080544
Ca	8	7.2300	17.4800	9.426250	3.3734126
Mg	8	8.8000	17.3300	10.755000	2.7540153
Cl	8	65.0000	89.0000	75.750000	8.3964278
CO_3	8	11.1200	22.8500	13.371250	3.9237243
SO_4	8	90.0000	163.0000	111.625000	27.5625911
NO_3	8	.6000	2.4000	1.127500	.5495908
TURB	8	1.3300	62.1000	9.368750	21.3104793
TDS	8	328.0000	524.0000	364.000000	66.4637388
Cr	8	.0013	.0075	0.004338	.0021287
Co	8	.0001	.0003	0.000213	.0000835
Ni	8	.0026	.0075	0.005175	.0018987
Fe	8	.1032	.3684	.221875	.0963795
Zn	8	.0185	.0532	.040200	.0124314
Valid N(listwise)	8				

Table 4: Descriptive Statistics of Physico-chemical and heavy metals of Keenjhar Lake (Post-Monsoon)

	N	Minimum	Maximum	Mean	Std.Deviation
pH	8	7.3500	8.0200	7.803750	.2090070
EC	8	520.0000	827.0000	578.375000	103.0574562
Na	8	36.1000	78.5900	44.855000	14.0298681
K	8	2.3300	4.5900	3.080000	.6837084
Ca	8	7.0100	16.9600	9.143750	3.2741932
Mg	8	8.3600	16.8100	10.410000	2.6891316
Cl	8	63.0500	86.3000	73.473750	8.1377760
CO_3	8	10.6800	21.9400	12.837500	3.7674044
SO_4	8	86.4000	156.5000	107.060000	26.4948534
NO_3	8	.5800	2.3000	1.081250	.5260483
TURB	8	1.2800	59.6000	8.990000	20.4531772
TDS	8	315.0000	503.0000	345.437500	63.7928777
Cr	8	.0012	.0070	.004000	.0020270
Co	8	.0001	.0010	.000250	.0003071
Ni	8	.0019	.0067	.004350	.0019324
Fe	8	.0900	.3150	.195113	.0829316
Zn	8	.0135	.0489	.033563	.0117105
Valid N(listwise)	8				

3.3. Correlation Analysis

To intercept correlation, four pieces of information are important; The numerical value of the correlation coefficient, the sign of the correlation coefficient, the statistical significance of the correlation and the effect size of the correlation. The Pearson correlation in Pre and Post-Monsoon analysis of seventeen parameters of Physico-chemical and heavy metals are shown in Table 5 and Table 6.

3.3.1 *Physico-chemical Parameters*

Correlation analysis of physico-chemical parameters in pre-monsoon, showed very strong correlation between Na^{+}-EC (r = 0.912), K^{+}-EC (r = 0.785), Ca^{+2}-EC (r = 0.932), Mg^{+2}-EC (r = 0.897), CO_3^{-2}-EC (r = 0.925), Turb-EC (r = 0.974), TDS-EC (r = 0.999); K^{+}-Na^{+} (r= 0.967), Ca^{+2}-Na^{+} (r= 0.961), Mg^{+2}-Na^{+} (r= 0.995), CO_3^{-2}-Na^{+} (r= 0.990), Turb-Na^{+} (r= 0.970), TDS-Na^{+} (r= 0.912); Ca^{+2}-K^{+} (r = 0.910), Mg^{+2}-K^{+} (r = 0.970), CO_3^{-2}-K^{+} (r = 0.953), Turb-K^{+} (0.892), TDS-K^{+} (r = 0.784); Mg^{+2}-Ca^{+2} (r = 0.941), CO_3^{-2}-Ca^{+2} (r = 0.989), Turb-Ca^{+2} (r = 0.986), TDS-Ca^{+2} (r = 0.934); CO_3^{-2}-Mg^{+2} (r = 0.980), Turb-Mg^{+2} (r = 0.963), TDS-Mg^{+2} (r = 0.894); Turb-CO_3^{-2} (r= 0.978), TDS-CO_3^{-2} (r= 0.925); Turb-SO_4^{-2} (r= 0.762); TDS-Turb(r =0.972). Correlation analysis of physico-chemical parameters in post-monsoon, showed very strong correlation between Na^{+}-EC (r = 0.912), K^{+}-EC (r = 0.784), Ca^{+2-}EC (r = 0.932), Mg^{+2}-EC (r = 0.869), CO_3^{-2}-EC (r = 0.925), Turb-EC (r = 0.974), TDS-EC (r = 0.999); K^{+}-Na^{+} (r= 0.967), Ca^{+2}-Na^{+} (r= 0.961), Mg^{+2}-Na^{+} (r= 0.994), CO_3^{-2}-Na^{+} (r= 0.990), Turb-Na^{+} (r= 0.970), TDS-Na^{+} (r= 0.912); Ca^{+2}-K^{+} (r = 0.911), Mg^{+2}-K^{+} (r = 0.973), CO_3^{-2}-K^{+} (r = 0.953), Turb-K^{+} (0.892), TDS-K^{+} (r = 0.784); Mg^{+2}-Ca^{+2} (r = 0.938), CO_3^{-2}-Ca^{+2} (r = 0.989), Turb-Ca^{+2} (r = 0.966), TDS-Ca^{+2} (r = 0.933); CO_3^{-2}-Mg^{+2} (r = 0.978), Turb-Mg^{+2} (r = 0.960), TDS-Mg^{+2} (r = 0.887); Turb-CO_3^{-2} (r= 0.977), TDS-CO_3^{-2} (r= 0.925); Turb-SO_4^{-2} (r= 0.763); TDS-Turb(r =0.972). These strong positive relationship are an indication of common source. This revealed parameters to be of the governed by the same geochemical factor and also of the same anthropogenic source [18-21].

3.3.2 *Heavy metal correlation*

Correlation analysis of heavy metals in pre-monsoon, showed very strong correlation between Co-Fe (r = 0.896), Ni-Zn (r = 0.835). Heavy metals showing very high correlation may indicate same source. Co showed positive correlation with Zn (r = 0.587), Ni with Fe (r = 0.544) and Fe with Zn (r = 0.692). Fe and Co comes mainly from Industrial activities/ Effluent through untreated domestic sewage dischatges [18]. Zn and Ni finds its main source from processing units. Correlation analysis of heavy metals in post-monsoon, showed very strong correlation between Ni-Zn (r = 0.729) and Cr showed positive relationship with Co (r = 0.61). Co and Cr comes mainly from anthropogenic activities [19].

Table 5: Pearson correlation of Physico-chemical and heavy metals of Keenjhar Lake (Pre-Monsoon)

	pH	EC	Na	K	Ca	Mg	$C0_3$	SO_4	NO_3	TUR	TDS	Cr	Co	Ni	Fe	Zn
pH	1															
EC	-.146	1														
Na	-.149	.921	1													
K	-.141	.785	.967	1												
Ca	-.317	.932	.961	.910	1											
Mg	-.061	.897	.995	.970	.941	1										
Cl	.261	.600	.255	.033	.316	.252	1									
CO_3	-.225	.925	.990	.953	.989	.980	.246	1								
SO_4	.162	.737	.657	.592	.675	.665	.617	.673	1							
NO_3	-.800	-.306	-.193	-.094	-.065	-.258	-.583	-.132	-256	1						
TURB	-.134	.974	.970	.892	.966	.963	.448	.976	.762	-.236	1					
TDS	-.150	.999	.921	.784	.934	.894	.604	.925	.746	-.300	.972	1				
Cr	-.554	-.467	-.468	-.470	.391	-.533	-.417	-.449	-815	.478	-.546	-.461	1			
CO	.455	-.043	-.159	-.248	-.296	-.115	.250	-.228	-.004	-.376	-.069	-.070	-.317	1		
Ni	.153	-.647	-.428	-.290	-.559	-.384	-.742	-.483	-.764	.110	-.557	-.670	.306	.336	1	
Fe	.177	-.066	-.117	-.166	-.213	-.079	-.008	-.158	-.194	-.133	-.058	-.102	-.154	.896	.544	1
Zn	.335	-.374	-.132	-.002	-.328	-072	-.570	-.215	-.315	.002	-.232	-.399	-.162	.587	.835	.692

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Table 6: Pearson correlation of Physico-chemical and heavy metals of Keenjhar Lake (Post-Monsoon)

	pH	EC	Na	K	Ca	Mg	C0$_3$	SO$_4$	NO$_3$	TUR	TDS	Cr	Co	Ni	Fe	Zn
pH	1															
EC	-.233	1														
Na	-.230	.912	1													
K	-.212	.784	.967	1												
Ca	-.392	.932	.961	.911	1											
Mg	-.143	.889	.994	.973	.938	1										
Cl	.207	.600	.256	.033	.316	.237	1									
CO$_3$	-.302	.925	.990	.953	.989	.978	.277	1								
SO$_4$	.092	.734	.659	.596	.676	.666	.611	.675	1							
NO$_3$	-.763	-.303	-.193	-.093	-.064	-.246	-.581	-.131	-.251	1						
TURB	-.220	.974	.970	.892	.966	.960	.448	.977	.763	-.235	1					
TDS	-.235	.999	.912	.784	.933	.887	.604	.925	.742	-.300	.972	1				
Cr	-.492	-.437	-.451	-.458	-.364	-.523	-.375	-.427	-.789	.456	-.524	-.430	1			
Co	-.865	-.216	-.169	-.117	-.003	-.238	-.477	-.092	-.333	.956	-.195	-.214	.611	1		
Ni	.137	-.585	-.395	-.282	-.526	-.350	-.691	-.454	-.799	.060	-.523	-.607	.313	.046	1	
Fe	.093	.015	-.055	-.113	-.130	-.014	.037	-.084	-.154	-.137	.015	-.019	-.230	-.119	.519	1
Zn	.233	-.351	-.073	.061	-.280	-.012	-.645	-.165	-.371	.075	-.209	-.370	-.082	-.058	.778	.523

3.4. Lake water pollution sources apportionment using Principal component analysis

Water systems of lakes are affected by the natural processes such as erosion of minerals and dissolution of nutrients from the overlying rocks as well as anthropogenic influences from industrial and agricultural activities. Multivariate statistical methods have been widely applied in environmental data reduction and interpretation of multiconstituent chemical and physical measurements. These techniques have been applied for rapid solution for pollution problems. In this regard, PCA is a very powerful multivariate statistical analysis method technique which is applied to reduce the dimensionality of a data set consisting of a large number of inter-related variables, while retaining as much as possible the variability present in data set [22-28]. In addition, it allows assessing the association between variables, since they indicate participation of individual chemicals in several influence factors. The correlation measures how well the variance of each constituent can be explained by relationship with each of the others and PC provides information on the most meaningful parameters, which describe the whole data set affording data reduction with minimum loss of original information.

The main purpose of PCA is to reduce the contribution of less significant variables to simplify even more of the data structure coming from PCA. Tabel 7 and Table 8 (Pre and Post-monsoon) summarize the PCA result including the loadings, the percent of variance and the % of cumulative variance. Factor loadings values of > 0.75, between 0.75-0.5 and 0.5-0.3 are classified as Strong, Moderate and weak based on their absolute values.

In Pre-Monsoon, PC1 accounts for 54.1% of the total variance and is dominated by the strong factor loading for EC (0.97), Na^{+} (0.945), K^{+} (0.864), Ca^{+2} (0.959), Mg^{+2} (0.936), CO_3^{-2}(0.959), SO_4^{-2} (0.825), Turb (0.983), TDS (0.974). PC2 account for 19.5% of the variance and is dominated by Co and pH having strong factor loading of 0.871 and 0.769. For PC1, EC, Na^{+}, K^{+}, Ca^{+2}, Mg^{+2}, CO_3^{-2}, SO_4^{-2},Turb and TDS have the highest factor loading value and showed that these are the most influential variable for the factor or principal component. It also reflects that overloading of EC, Na^{+}, K^{+}, Ca^{+2}, Mg^{+2}, CO_3^{-2}, SO_4^{-2},Turb and TDS are responsible for the heaviest pollution problem in the lake. For PC2, Co and pH have the highest factor loading value, suggesting pH and heavy metals are also major environmental problem in Lake.

In Post-Monsoon, PC1 accounts for 53.8% of the total variance and is dominated by the strong factor loading for EC (0.969), Na^{+} (0.944), K^{+} (0.862), Ca^{+2} (0.947), Mg^{+2} (0.936), CO_3^{-2} (0.953), SO_4^{-2} (0.832), Turb (0.986), TDS (0.972). For PC1, EC, Na^{+}, K^{+}, Ca^{+2}, Mg^{+2}, CO_3^{-2}, SO_4^{-2},Turb and TDS have the highest factor loading value and showed that these are the most influential variable for the factor or principal component. It also reflects that overloading of EC, Na^{+}, K^{+}, Ca^{+2}, Mg^{+2}, CO_3^{-2}, SO_4^{-2},Turb and TDS are responsible for the heaviest pollution problem in the lake. PC2 account for 19.7% of the variance and is dominated by Zn having strong factor loading of 0.897. For PC2, Zn has the highest factor loading value, suggesting that Zn pollution is also a major environmental pollutant in Lake.This is good agreement with the findings in correlation analysis nd PCA. The above mention agreements have been summarised in Graph 1 (Component Plot of Physico-chemical and Heavy metals in Pre-Monsoon) and Graph 2 (Component Plot of Physico-chemical and Heavy metals in Post-Monsoon).

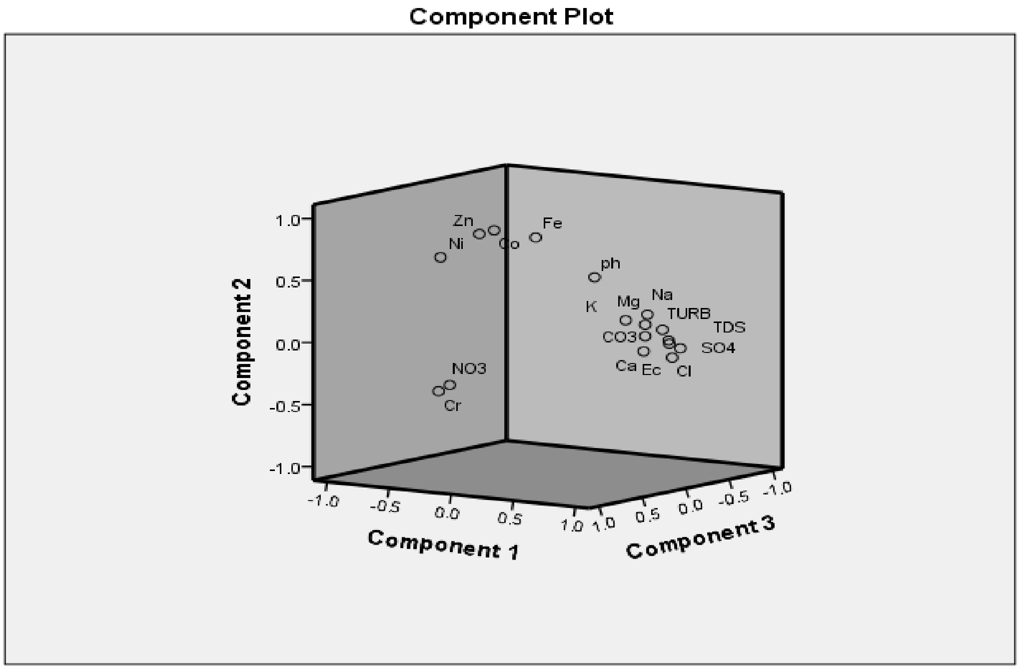
Table 7: Factor Analysis of Physico-chemical and heavy metals of Keenjhar Lake (Pre-Monsoon)

	Component			
	1	2	3	4
pH	-.099	.769	-.362	-.500
EC	.970	.050	-.011	.209
Na	.945	.018	.302	-.056
K	.864	-.021	.442	-.236
Ca	.959	-.165	.210	.046
Mg	.936	.099	.305	-.110
Cl	.514	.265	-.737	.338
CO_3	.958	-.063	.271	-.020
SO_4	.821	.173	-.290	-.091
NO_3	-.268	-.664	.426	.238
TURB	.983	.072	.146	.084
TDS	.974	.026	-.031	.194
Cr	-.561	-.612	.130	.290
Co	-.173	.871	.037	.430
Ni	-.676	.312	.620	-.111
Fe	-.212	.727	.366	.528
Zn	-.366	.618	.665	-.137
%Var	54.149	19.550	14.337	6.877
%Cum	54.149	73.699	88.036	94.913

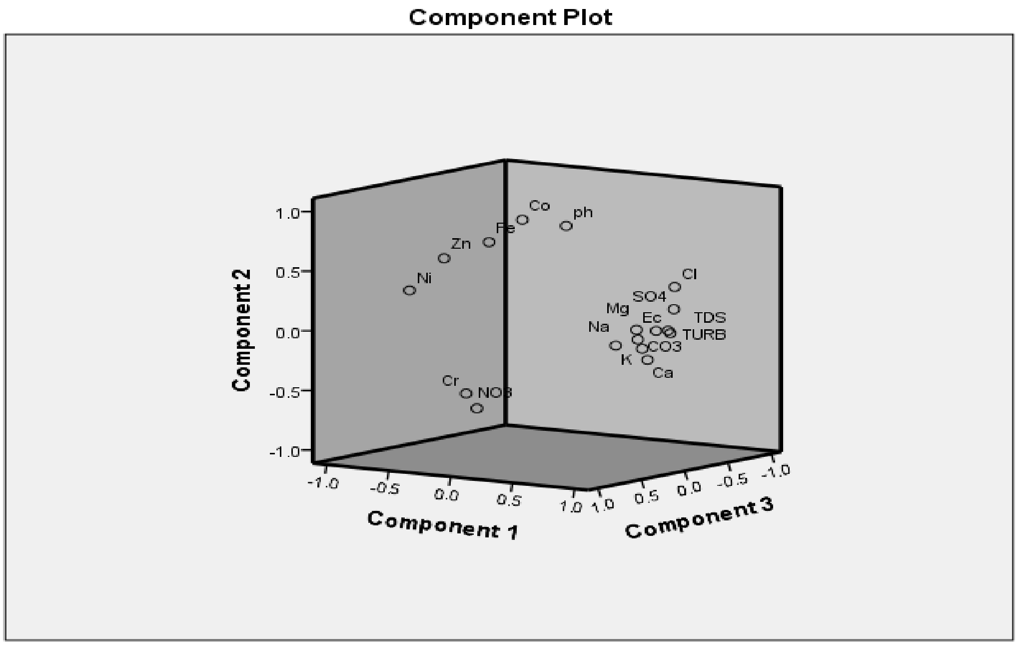
Table 8: Factor Analysis of Physico-chemical and heavy metals of Keenjhar Lake (Post-Monsoon)

	Component			
	1	2	3	4
pH	-.134	-.940	.090	-.275
EC	.969	.045	-.027	.214
Na	.944	.155	.258	-.071
K	.862	.212	.378	-.256
Ca	.947	.293	.072	-.001
Mg	.936	.080	.319	-.099
Cl	.527	-.466	-.565	.417
CO_3	.953	.220	.183	-.044
SO_4	.832	-.207	-.234	-.126
NO_3	-.304	.867	-.014	-.047
TURB	.986	.083	.120	.081
TDS	.972	.050	-.051	.192

Cr	-.572	.561	-.190	.130
Co	-.274	.926	-.092	.120
Ni	-.625	-.028	.728	.110
Fe	-.093	-.245	.577	.735
Zn	-.311	-.083	.897	-.086
%Var	53.825	19.738	14.488	6.061
%Cum	53.825	73.563	88.051	94.112



Graph 1: Component Plot of Physico-chemical and Heavy metals in Pre-Monsoon



Graph 2: Component Plot of Physico-chemical and Heavy metals in Post-Monsoon

Conclusion

1. Majority of parameters namely shows moderate to strong correlation among themselves. These strong positive relationships are an indication of common source. The revealed parameters to be of the governed by the same geochemical factor and also of the same anthropogenic source

2. This result was further confirmed through factor analysis indicating the main sources of pollution were anthropogenic, Municipal effluent, industrial waste effluent and raw sewerage (mining and drilling). Hence, lake water must be used for drinking only after proper treatments and proper monitoring of the lake should be carried our periodically.

3. Lake pollution is generally caused by various sources. one would have to implement sound watershed management and pollution controls to reduce the sources of pollutant. These management measures have included pollution reduction in industrial effluent releases; lakeside ecological remediation; clean-water diversion; and dredging. Highlights of these strategies are:
   i) Control and reduce exogenous pollutants in the basin: stricter discharge standards for municipal wastewater treatment plants and, manufacturing industries/companies should be encouraged and compelled by the regulatory agencies to treat their effluents before discharging into receiving water bodies.
   ii) Pollution interception and remediation: A grass-type wetland ecosystem should have a strong assimilative capacity for pollutants and can be used to improve water quality. Wetlands, which have nutrient removal and other ecological protection functions, have been constructed as a buffer zone around the lake in order to improve lake water quality.
   iii) Dredging: Contaminated sediment, at the bottom of a lake or riverbed, is especially difficult to remove. It can be removed by dredging, which is the process of removing the contaminated sediment and disposing of it in a safer location.
   iv) Water Quality: Lake water quality should be continuously monitored so that the level of pollution will be known and also to determine if the water is safe for drinking/ agricultural practices.

4. This study further demonstrates the application of statistical methods in assessing the Physico-chemical characteristics of the lake water and also to provide preliminary assessment of the lake water quality that will serve as a database for future investigations and monitoring of lake water quality in the study area.

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References

1. Pourang N., Nikouyan A. and Dennis J.H., *Environ. Monit. Assess*. 109 (2005) 293.
2. Garrett R.G., *Hum. Ecol. Risk Assess*. 6 (2000) 945.
3. Macfarlane G.R. and Burchett M.D., *Mar. Pollut. Bull*. 42 (2001) 233.
4. Youn-Joo A. and Donald H.K., *Environ. Poll*. 122 (2003) 253.
5. Ansari T.M., Marr IL. and Tariq N., *J. Appl. Sci*. 4 (2004) 1.
6. Arain M.B., Kazi T.G., Jamali M.K., Jalbani N., Afridi H.I. and Shah, A., *Chemosphere,* 70 (2008) 1845.
7. Assunta M., De Silva M. and Sacomani L.B., *Water Res*. 35 (2001) 1609.
8. Ghazanfar M., Javed M. and Hassan M., *Pak. J. Biol. Sci*. 3 (2000) 1962.
9. Javed M. and Hayat S., *Pak. Cong. Zool*. 16 (1996) 383.
10. Kamran T, Muhammad A., Salam A., Latif M. and Zahra T., *Pak. J. Biol. Sci*. 6 (2003) 1795.

11. Mehta and Jagat S., *NRF*.12 (1988) 69.
12. Kumar D. and Ahmed S., *Current Sci.* 84 (2003) 188.
13. Suk H. and Lee K., *Ground Water*. 37 (1999) 358.
14. Isaaks E.H. and Srivastava R.M., An introduction to applied geostatistics. New York: Oxford University. (1989).
15. Bengraine K. and Marhaba T., *J. Hazard. Mater*.100 (2003) 179.
16. Anonymous, EPA (US Environmental Protection Agency). Morbidity and Mortality: How Do We Value the Risk of Death and Illness? National Center for Environmental Economics, US EnvironmentalProtection Agency (2006).
17. American Public Health Association (APHA)., Standard method for the examination of water and waste water (20th edition) Washington D.C.(1998).
18. Maheshwari A, Sharma M. and Sharma D., *J. Mater. Environ. Sci. 2(4) (2011) 373.*
19. Mukhtar F, Bhat M.A., Bashir R. and Chisti H., *J. Mater. Environ. Sci.* 5 (2014)1178.
20. Ghanem M. and Ahmad W., *Mor. J. Chem*. 2(2014) 443.
21. Kumar A. and Sharma M.P, *J. Mater. Environ. Sci*. 5(2014) 95.
22. Fan X., Cui B., Zhao H., Zhang Z. and Zhang H., *Annual Conference (ISEIS), Procedia Environmental Sciences*. 2 (2010)1220.
23. Jianqin M., Jingjing G. and Xiaojie L. , *JORAE*. 1 (2010) 249.
24. Ougang Y., *Water Res*. 39 (2005) 2621.
25. Parinet B., Lhote A. and Legube B., *Ecol Model*.78 (2004) 295.
26. Reghunath R., Murthy T. and Raghavan B., *Water Res.* 36 (2002) 2437.
27. Singh K., Malik A., Mohan D. and Sinha S., *Water Res.* 38 (2004) 3980.
28. Yasmin N., Yahya S.M., Rahman A. and Siddiqui S.A., *AJBPR.* 4 (2013) *19.*