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Statistical Assessment of Water Quality Parameters for Pollution Source Identification in Deepor Beel Area, Guwahati, Assam

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ABSTRACT
This study was carried out in Deepor Beel to assess the water quality parameter by statistical analysis. The samples were collected from nine selected stations covering entire area. The lake's water quality was evaluated based on it's the locations, and the variations of seasons .Water Pollution issues were identified and quality classes were developed. The adaptability of aquatic life forms has also been demonstrated. 13 physico-chemical and four heavy metal parameters were examined in the lake water for such reasons. The results of the study suggest that non-point pollution that is, soil leaching and agricultural contamination may be the primary cause of pollution in this region. These results at the temporal and spatial scales recommend that water monitoring efforts in the future should be scale-sensitive to water management.

Keywords: water quality parameters , principal components analysis (PCA), water quality.

1. INTRODUCTION

Deepor Beel is quite important in both ecological and economical aspects, the quality of lake water plays the pivotal role in proper sustenance of the biological resources and livelihood of the local people. Developing an understanding of changes in the water quality of the lake is essential for the proper management of the environment and economy of this region. Natural processes (such as alterations in the ecosystem) and anthropogenic influences (such as rising water resource consumption, industrial, and agricultural activities, urbanization, Surface waters are not adequate for drinking, industrial, agricultural, recreational, or other uses due to precipitation inputs, erosion, and weathering of crustal nutrients. This was a longitudinal study involving the testing of water samples from the lake over a period of one years to assess temporal water quality trends (both qualitative and quantitative). Physicochemical parameters of the lake were assessed for determining the quality of water (Roy & Majumder, 2019). This study provides insight into changes in water quality of Deepor Beel. It is hoped that this information will help in the development of an improved management system. Assessment of water quality trends in Deepor Beel, Assam.

The aim of this paper is to carry out a systematic water quality analysis for all the entire seasons in order to know the seasonal temporal changes in water quality and analyze the concentration of water quality parameters by some statistical analysis in order to co-relate these parameters and know their effect in the area under study.

2. MATERIALS AND METHOD

2.1 Sample locations and sampling

Deepor Beel is situated in the Kamrup (M) district and it is the only Ramsar site in Assam. In Ramsar Convention on wetlands, 1971, Deepor Beel was declared as “Wetlands of International Importance”. Deepor Beel was declared Ramsar site in 2002. Its basin is drained by a system of rivulets and hill streams that connect the neighbouring hills and the forests to the river Brahmaputra through an outlet called the Khanajan. The study area is located at 26^{0}06’36.05” Nto 26^{0}08’11.48” N and 91^{0}37’44.97” E to 91^{0}40’35.48” E.

Table 2.1: Coordinates of sampling sites

SITE NO. (SITE NAME)	GPS LOCATION (LATTITUDE, LONGITUDE)
Near ASTU	26^{0}08’25.43” N , 91^{0}39’01” E
Near MCA building, AEC	26^{0}08’30.48” N , 91^{0}39’44.58” E
Near Tetelia	26^{0}06’44.04” N , 91^{0}39’12.82” E
Chakardeo village	26^{0}06’46.29” N , 91^{0}39’16.41” E
Mikir para, Rani	26^{0}08’8.24” N , 91^{0}39’16.41” E
Boragaon dumping site I	26^{0}06’57.56” N , 91^{0}40’35.48” E
Boragaon dumping site II	26^{0}06’36.05” N , 91^{0}38’39” E
Near GIMT	26^{0}07’21.62” N , 91^{0}37’44.97” E
Azara	26^{0}08’11.48” N , 91^{0}40’5.63” E

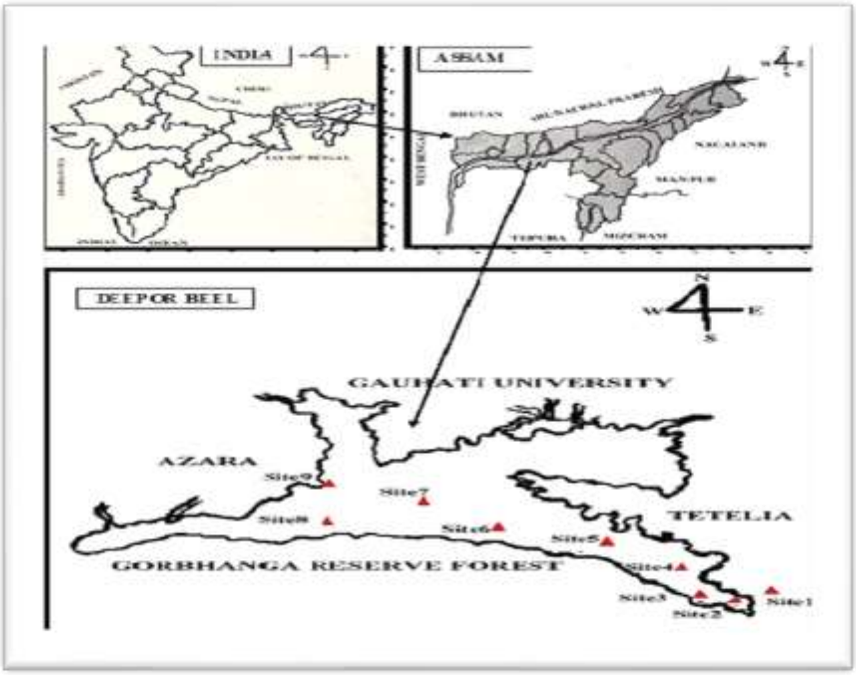

Fig 2. 1 : Image shows the study area of Deepor Beel

2.2 Determination of physicochemical parameters

Samples were taken from Deepor Beel in nine fixed sampling locations and data were collected through the entire four seasons. The analysis were made consistently throughout the study area(Fig 1). The sampling points were initially selected with eye estimation in such a way that they may spread throughout the mid-range of the entire surface of the lake. Samples were taken in the middle of 15th to 20th day of a month from a depth of 1 m to ensure a regular sampling pattern. Some physicochemical parameters like DissolvedOxygen (DO), Total Dissolved Solids (TDS), Electrical Conductivity (EC), pH andTemperature (T), salinity were estimated in situ with Multiparameter Water Quality Analyzing device. Other parameters like Total Hardness (TH), Chlorine content (Cl), and Biochemical Oxygen Demand (BOD) were estimated in laboratory.Samples were collected in 1-L Sample Bottles and kept in ice box immediately after collection. The bottles were brought in the laboratory within 10 h after collection and preserved in refrigerator to estimate the parameters on the next day. In this study

World Health Organization (WHO) (BIS, 2012) and Indian Standard 10500: 2012 (IS 10500: 2012) Guidelines (Moharana et al., 2014; WHO, 2008) were followed for the permissible limits of the Water Quality Parameters (WQP).

2.3. Data treatment and multivariate statistical Analysis

The statistical analysis of the water analysis results was done using the SPSS statistical package software. Descriptive statistical analysis, including One-way ANOVA, significance (0.01 and 0.05) was done for the stations and seasonal. In addition, Hierarchical Cluster Analysis (HCA) techniques were utilized to perform multivariate analysis of the lake water quality data set (Singh et al., 2004; Shrestha and Kazama, 2007; Wu et al., 2010). The HCA assessed similarity using Ward's method and Euclidean distance .A collection of methods called hierarchical cluster analysis (HCA) is used to arrange large data sets based on differences or similarities.

3. RESULTS AND ANALYSIS

Testing of the water quality parameters were done season-wise i.e., Autumn (October, 2022 – December, 2022), winter season (January, 2023 – March, 2023), spring season (April, 2023 – June, 2023) and summer season (July, 2023 – September, 2023). The results obtained in this testing have been presented in tabular form and are statistically analyzed.

Table 3.1: Concentrations of Water Quality Parameters of the sampling sites for Autumn Season

Water quality Parameters	*SITE 1*	*SITE 2*	*SITE 3*	*SITE 4*	*SITE 5*	*SITE 6*	*SITE 7*	*SITE 8*	*SITE 9*
Temperature (˚C)	24.8	25.5	25.2	23	22.5	24	23.4	24.2	23.5
pH	7.2	7.35	7.42	6.25	6.45	6.92	6.97	6.78	6.59
Dissolved oxygen (mg/l)	5.6	5.4	3.5	4.89	4.1	3	3.6	4.8	3.8

Total Dissolved Solids (mg/l)	190	187.5	196.2	180	108	155.6	156.2	70	122.7
Salinity (ppt)	0.271	0.295	0.289	0.152	0.130	0.232	0.231	0.140	0.180
Electrical Conductivity (ms/cm)	0.365	0.234	0.387	0.165	0.175	0.309	0.312	0.155	0.238
Biological Oxygen Demand (mg/l)	1.3	1.9	2.47	2.1	2.7	3.6	3.1	2.03	2.3
Total Hardness (mg/l)	115	90	120	125	130	110	105	112	85
Chloride (mg/l)	100	105	60	95	50	30	35	75	80
Iron (mg/l)	0.95	0.53	0.60	1.1	1.45	2.52	2.78	1.03	1.12
Nitrate (mg/l)	0.007	0.009	0.045	0.03	0.08	0.15	0.20	0.06	0.01
Lead (mg/l)	0.022	0.095	0.02	0.04	0.08	0.12	0.19	0.027	0.03

The above table is a demonstration of the concentration of the 13 different water parameters for the 9 different sampling locations. The values listed are based on laboratory analysis of the water samples for the first season of our study.

Table 3.2: Concentrations of Water Quality Parameters of the sampling sites for Winter Season

Water quality parameters	*SITE 1*	*SITE 2*	*SITE 3*	*SITE 4*	*SITE 5*	*SITE 6*	*SITE 7*	*SITE 8*	*SITE 9*
Temperature (˚C)	21.5	23	24.2	22	22.5	23.3	23	23.8	22.5
pH	6.94	7.15	7.25	5.85	6.3	6.5	6.78	6.2	6.1
Dissolved oxygen (mg/l)	6.2	5.7	4.2	5.1	6	4.2	3.9	5.2	4.5
Total Dissolved Solids (mg/l)	235	205	214.8	195	145.6	169.5	141	110	179.2
Salinity (ppt)	0.294	0.350	0.275	0.220	0.142	0.200	0.365	0.155	0.128
Electrical Conductivity (ms/cm)	0.405	0.245	0.355	0.205	0.178	0.292	0.325	0.207	0.250
Biological Oxygen Demand (mg/l)	1.05	1.5	2.3	1.75	1.1	2.25	4.8	1.7	1.97
Total Hardness (mg/l)	125	95	130	135	140	120	115	122	90
Chloride (mg/l)	90	110	75	70	45	35	50	70	65
Iron (mg/l)	0.97	0.63	0.68	1.22	1.49	2.6	2.83	1.03	1.12

Nitrate (mg/l)	0.005	0.007	0.01	0.025	0.04	0.13	0.17	0.038	0.009
Lead (mg/l)	0.01	0.049	0.016	0.037	0.063	0.095	0.099	0.025	0.028
Turbidity(NTU)	10	10	9	8	10	15	14	6	5

The above table is a demonstration of the concentration of the 13 different water parameters for the 9 different sampling locations for the second season of our study.

Table 3.3: Concentrations of Water Quality Parameters of the sampling sites for Spring Season

Water quality parameters	***SITE 1***	***SITE 2***	***SITE 3***	***SITE 4***	***SITE 5***	***SITE 6***	***SITE 7***	***SITE 8***	***SITE 9***
Temperature (˚C)	29	28.4	29	29.5	28.5	29.4	28	29.2	28.6
pH	7.04	7.2	7.3	6.12	6.5	7.12	7.09	6.5	6.45
Dissolved oxygen (mg/l)	5.9	5.4	3.9	4.95	5.85	4.06	3.87	5	4.16
Total Dissolved Solids (mg/l)	240	213	220.8	198	159.3	170	143	115	184
Salinity (ppt)	0.304	0.275	0.32	0.386	0.182	0.204	0.372	0.164	0.130
Electrical Conductivity (ms/cm)	0.397	0.284	0.350	0.216	0.198	0.297	0.365	0.208	0.257
Biological Oxygen Demand (mg/l)	1.12	1.54	4.35	1.8	1.23	3.48	5	1.7	2
Total Hardness (mg/l)	123	90	127	131	136	112	105	114	86
Chloride (mg/l)	95	119	77	74	47	39	55	73	69
Iron (mg/l)	0.96	0.59	0.62	1.15	1.39	2.55	2.65	1	1.04
Nitrate (mg/l)	0.006	0.008	0.018	0.03	0.05	0.18	0.2	0.043	0.01
Lead (mg/l)	0.009	0.043	0.01	0.038	0.032	0.085	0.090	0.012	0.015
Turbidity(NTU)	9	10	10	8	10	14	13	7	7

The above table is a demonstration of the concentration of the 13 different water parameters for the 9 different sampling locations for the third season of our study.

Table 3.4: Concentrations of Water Quality Parameters of the sampling sites for Summer Season

Water quality parameters	***SITE 1***	***SITE 2***	***SITE 3***	***SITE 4***	***SITE 5***	***SITE 6***	***SITE 7***	***SITE 8***	***SITE 9***
Temperature (˚)	31	31.4	28	28.5	26	27.5	29	30	29.6
pH	7.12	7.27	7.4	6.95	7.06	8	7.89	7.10	7.3
Dissolved oxygen (mg/l)	5.45	5.23	3.5	4.12	5.3	3.1	2.93	4.67	3.85

Total Dissolved Solids (mg/l)	255	230	238	216	168.5	185	160	130	200
Salinity (ppt)	0.308	0.29	0.325	0.402	0.196	0.215	0.405	0.174	0.149
Electrical Conductivity (ms/cm)	0.4	0.283	0.350	0.218	0.199	0.292	0.368	0.200	0.260
Biological Oxygen Demand (mg/l)	1.15	1.67	4.40	2	1.2	4.89	6.7	1.8	4.2
Total Hardness (mg/l)	120	82	127	130	127	104	95	103	79
Chloride (mg/l)	98	100	84	75	48	65	90	82	70
Iron (mg/l)	0.90	0.54	0.55	1.10	1.26	1.55	1.65	0.96	0.85
Nitrate (mg/l)	0.0058	0.007	0.014	0.028	0.042	0.1	0.19	0.038	0.009
Lead (mg/l)	0.01	0.053	0.019	0.043	0.038	0.01	0.012	0.037	0.04
Turbidity(NTU)	9.5	11	10	7.5	10	15	14	6	5

The above table is a demonstration of the concentration of the 13 different water parameters for the 9 different sampling locations for the fourth season of our study.

3.1 Principal Component Analysis(PCA):

Principal component analysis was used to decrease the dimensional space of the large dataset in order to improve the clustering. In PCA analysis contains three components, 13 physico-chemical parameters were categorized. PCA's classified the factor loadings as '**strong', 'moderate' and 'weak'**, matching to absolute loading values of **>0.75, 0.75-0.50 and 0.50-0.30,** respectively (Liu et al., 2003). PCA is done for four different seasons i.e. Autumn, Winter, Spring and Summer. The results of calculations were shown in Table 3.1.1, Table 3.1.2, Table 3.1.3 and Table 3.1.4. According to Hair et al. (2009), the choice of the number of major components to be retained in the number of major components released before a clear break between scree.

<u>PCA for Autumn</u>

PCA revealed that three components explain **84.620**% of the total variance, with the salinization process and anthropogenic activities being the main factors controlling the surface water quality variability. The PCA results are shown in Table 3.1.1. The PCA approach identified three components that have the most critical loading (Fig 3.1.2)

Table: 3.1.1

Variable	**PC 1**	**PC 2**	**PC 3**
EIGEN VALUES	5.392	4.432	1.177
% of Variance	41.477	34.091	9.052
Cumulative %	41.477	75.568	84.620
TEMPERATURE(0C)	0.810	-0.277	-0.223
pH	0.896	0.003	-0.099
DO	-0.030	-0.959	-0.048

TDS	0.783	-0.296	0.235
SALINTY	0.970	-0.104	0.125
EC	0.893	0.276	0.015
BOD	-0.086	0.868	0.395
TOTAL HARDNESS	-0.162	0.089	-0.078
CHLORIDE	0.054	-0.938	-0.289
IRON	-0.158	0.740	0.697
NITRATE	-0.055	0.757	0.658
LEAD	0.025	0.377	0.886
TURBIDITY	0.642	0.135	0.737

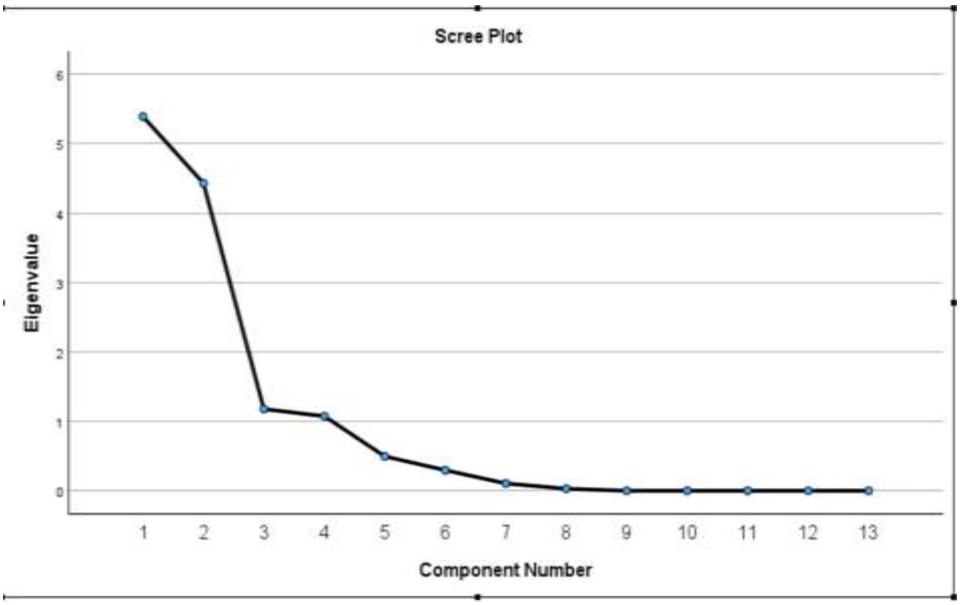

Fig 3.1.1: Scree-plot for the principal component model of the monitoring data

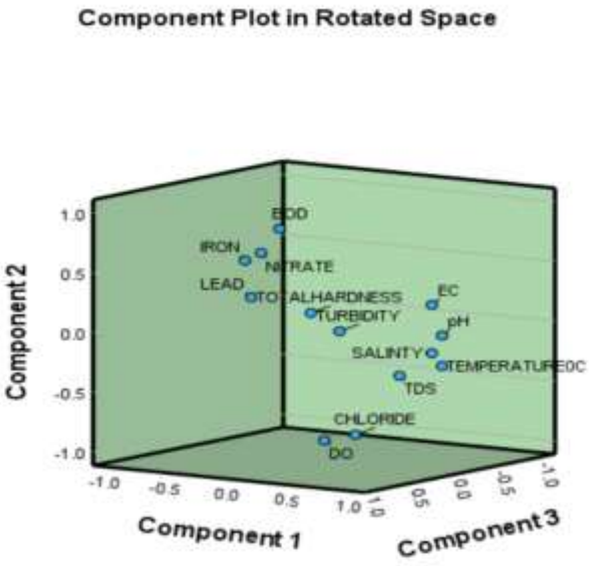

Fig 3.1.2 : Component plot

The first component (PCA1) explains 41.477% of the total variance and encompasses the following main parameters EC, TDS, salinity, and pH were strongly related. The significant variables (EC, TDS, salinity, pH) within PCA1 followed the same direction and showed a major increase related to salinity. PCA1 demonstrates that the salinization process is the main factor controlling the surface water quality variability and the importance of mineralization process.

The second component (PCA2) explains 34.091% of the total variance and was assembled by DO , BOD, Chloride, Iron and Nitrate showing high correlations among themselves towards the same direction (Table). PC 2 demonstrates the high concentration of BOD and sets an inverse correlation with DO which seems an increased cause of pollution and a higher concentration of iron and nitrate also effecting the water quality.

The third component (PCA3) accounts for 9.052% of the total variance and describes the significant contributions of Lead and Turbidity (Table 3.1.1 and Figure 3.1.2), disclosing good correlations among themselves. It shows that higher lead concentration effecting turbidity of surface water.

PCA for Winter

The winter PCA reveals the three components explaining **78.536**% of the total variance. The PCA results are shown in Table 3.1.2. The PCA approach identified three components that have the most critical loading (Fig 3.1.4)

Table 3.1.2

Variable	PC 1	PC 2	PC 3
EIGEN VALUES	5.314	3.286	1.609
% of Variance	40.881	25.275	12.380
Cumulative %	40.881	66.155	78.536
TEMPERATURE(0C)	-0.006	0.027	0.948
pH	-0.080	0.904	0.220

DO	-0.499	-0.030	-0.702
TDS	-0.401	0.682	-0.359
SALINTY	0.229	0.856	-0.035
EC	0.077	0.845	0.055
BOD	0.724	0.203	0.446
TOTAL HARDNESS	0.052	-0.059	-0.064
CHLORIDE	-0.694	0.470	-0.201
IRON	0.984	-0.085	0.050
NITRATE	0.967	0.015	0.212
LEAD	0.935	-0.076	0.038
TURBIDITY	0.807	0.454	-0.056

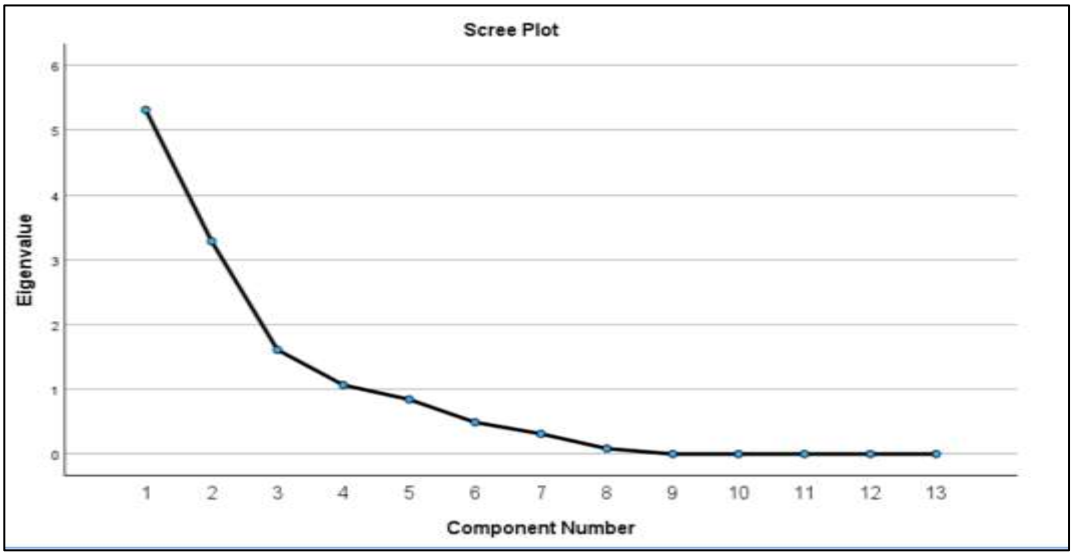

Fig 3.1.3: Scree-plot for the principal component model of the monitoring data

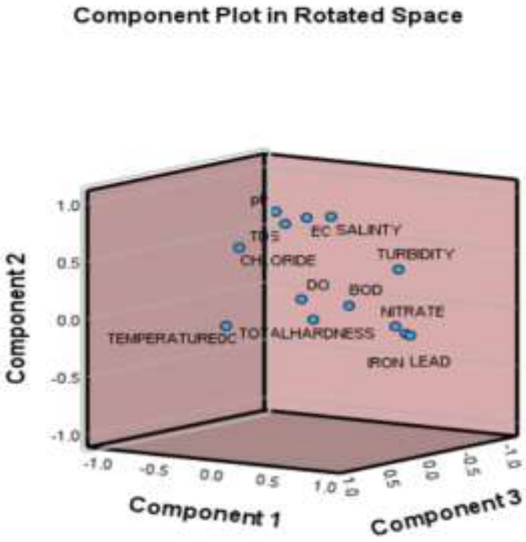

Fig 3.1.4: Component plot

The first component (PCA1) explains **40.881**% of the total variance and encompasses the following main parameters iron, nitrate, lead and turbidity were strongly related. PC 1 demonstrates metallic pollution due to which turbidity is also increased.
The second component (PCA2) explains **25.275**% of the total variance and was assembled by pH, Salinty and EC showing high correlations among themselves towards the same direction .
PCA for Spring
The spring PCA reveals the three components explaining **76.485**% of the total variance. The PCA results are shown in Table 3.1.3

Table 3.1.3

Variable	PC 1	PC 2	PC 3
EIGEN VALUES	5.394	2.887	1.663
% of Variance	41.489	22.207	12.789
Cumulative %	41.489	63.696	76.485
TEMPERATURE(0C)	-0.235	-0.131	0.145
pH	0.183	0.754	0.204
DO	-0.278	-0.047	-0.943
TDS	-0.502	0.717	-0.135
SALINTY	0.151	0.724	-0.017
EC	0.098	0.857	0.220
BOD	0.508	0.364	0.751
TOTAL HARDNESS	0.105	0.087	-0.283
CHLORIDE	-0.695	0.430	-0.290
IRON	0.949	-0.048	0.192
NITRATE	0.946	0.033	0.282
LEAD	0.904	0.128	0.111
TURBIDITY	0.834	0.428	0.123

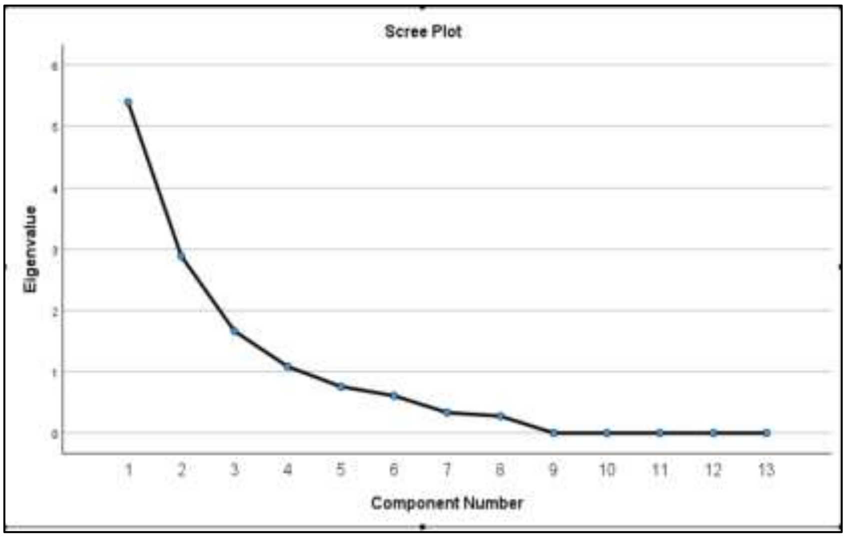

Fig 3.1.5: Scree-plot for the principal component model of the monitoring data

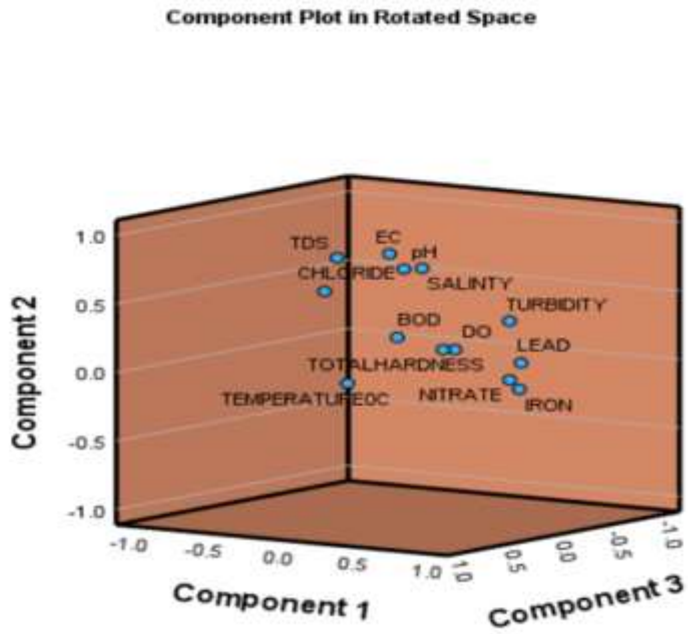

Fig 3.1.6: Component plot

The first component (PCA1) explains **41.489**% of the total variance and encompasses the following main parameters iron, nitrate,lead and turbidity were strongly related . PC 1 demonstrates metallic pollution due to which turbidity is also increased.

The second component (PCA2) explains **22.207**% of the total variance and was assembled by pH, and EC showing high correlations among themselves towards the same direction (Table 3.1.3).

The third component (PCA3) accounts for 12.789% of the total variance and describes the significant contributions of DO and BOD. It sets an inverse correlation among them.

PCA for Summer

The summer PCA reveals the three components explaining **79.485**% of the total variance. The PCA results are shown in Table 3.1.4.

Table 3.1.4:

Variable	PC 1	PC 2	PC 3
EIGEN VALUES	5.276	3.175	1.882
% of Variance	40.584	24.423	14.477
Cumulative %	40.584	65.007	79.485
TEMPERATURE(0C)	-0.288	0.255	0.868
pH	0.939	0.093	0.135

DO	-0.826	-0.014	0.023
TDS	-0.407	0.750	0.133
SALINTY	0.185	0.734	-0.080
EC	0.354	0.826	0.284
BOD	0.897	0.064	0.140
TOTAL HARDNESS	-0.271	0.388	-0.844
CHLORIDE	-0.076	0.612	0.713
IRON	0.748	-0.184	-0.411
NITRATE	0.917	-0.016	-0.094
LEAD	-0.623	-0.525	0.202
TURBIDITY	0.705	0.370	-0.154

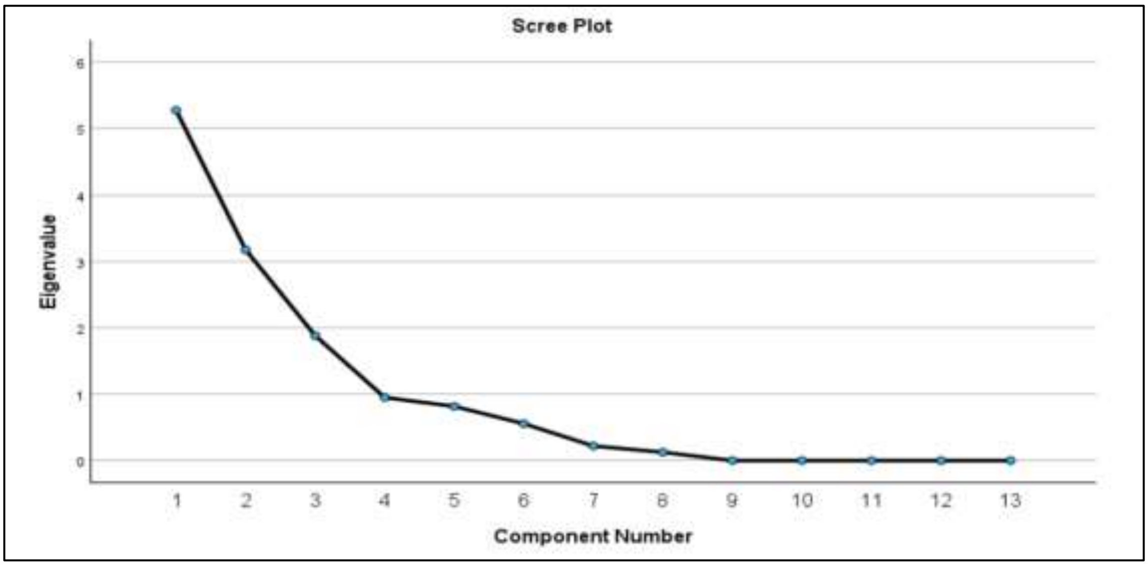

Fig 3.1.7: Scree-plot for the principal component model of the monitoring data

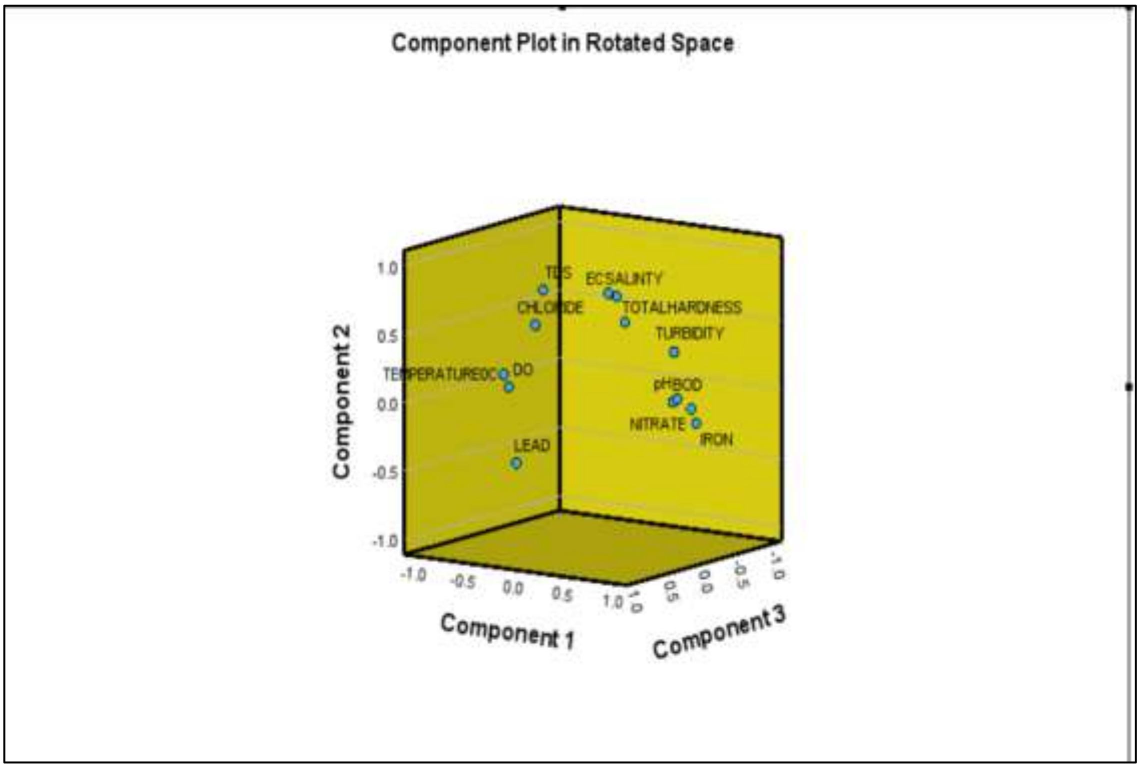

Fig 3.1.8: Component plot

The first component (PCA1) explains **40.584**% of the total variance and encompasses the following main parameters pH, BOD,iron ,nitrate were strongly related and DO is negatively related with BOD.
The second component (PCA2) explains **24.423**% of the total variance and was assembled by TDS and EC showing high correlations among themselves towards the same direction (Table 3.1.4).
The third component (PCA 3) demonstrates a strong negative value of total hardness.

K- MEANS ANALYSIS

The spatial distribution , the descriptive statistics (Table 3.1.5), and the graphical representation of the means (Fig.) of the four detected seasons signify the spatial variability of the hydrochemistry among the seasons. The first season Autumn(9 observations) exhibits higher concentration of nitrate(0.07mg/l) and lead(0.07mg/l) relative to other seasons . The nitrate concentration is under permissible limit (<45mg/l) but lead concentration is seems to be beyond permissible limit (>0.01mg/l). The second season exhibits higher concentration of DO (5mg/l) which signifies lesser pollution in winter season. Total hardness is also found in higher concentration (119.11mg/l). As per BIS total hardness ranges between 60mg/l to 120mg/l are classified as soft water. The winter season also consumes higher concentration of iron (1.5mg/l) which goes beyond the permissible limit of iron (>0.3 mg/l). The third season i.e. spring season samples are highly loaded with EC concentration (0.29 mg/l) and turbidity (9.78 NTU). Lastly the summer season's samples are bringing highest pH level(7.34) ,TDS(198.06 mg/l), salinity(0.27 mg/l), BOD(3.11 mg/l) and chloride content (79.11 mg/l). The highest BOD concentration notifies the highest pollution in summer season among all the four seasons.

Table 3.1.5:

Column1	TEMPERATUR	pH	DO	TDS	SALINTY	EC	BOD	TOTAL HARDNESS	CHLORIDE	IRON	NITRATE	LEAD	TURBIDITY
AUTUMN (n=9)													
MAXIMUM	25.50	7.42	5.60	196.20	0.30	0.39	3.60	130	105	2.78	0.20	0.19	13
MINIMUM	22.50	6.25	3	70	0.13	0.16	1.30	85	30	0.53	0.01	0.02	6
MEAN	24.01	6.90	4.30	151.80	0.21	0.26	2.39	110.22	70	1.34	**0.07**	**0.07**	9.39
Std. Deviation	1.01	0.39	0.91	43.29	43.29	0.09	0.68	15.01	27.84	0.79	0.07	0.06	2.47
WINTER (n=9)													
MAXIMUM	24.20	7.25	6.20	235	0.37	0.41	4.80	140	110	2.83	0.17	0.10	15
MINIMUM	21.50	5.85	3.90	110	0.13	0.18	1.05	90	35	0.63	0.01	0.01	5
MEAN	22.87	6.56	**5**	177.23	0.24	0.27	2.05	**119.11**	67.78	**1.40**	0.05	0.05	9.67
Std. Deviation	0.85	0.49	0.85	39.89	0.09	0.08	1.12	16.94	23.06	0.79	0.06	0.03	3.28
SPRING (n=9)													
MAXIMUM	29.50	7.30	5.90	240	0.39	0.40	5	136	119	2.65	0.20	0.09	14
MINIMUM	28	6.12	3.87	115	0.13	0.20	1.12	86	39	0.59	0.01	0.01	7
MEAN	28.84	6.81	4.79	182.57	0.26	**0.29**	2.47	113.78	72	1.33	0.06	0.04	**9.78**
Std. Deviation	0.50	0.42	0.82	39.93	0.09	0.07	1.43	17.56	24.44	0.76	0.08	0.03	2.44
SUMMER (n=9)													
MAXIMUM	31.40	8	5.45	255	0.41	0.40	6.70	130	100	1.65	0.19	0.05	15
MINIMUM	26	6.95	2.93	130	0.15	0.20	1.15	79	48	0.54	0.01	0.01	5
MEAN	29	**7.34**	4.24	**198.06**	**0.27**	0.28	**3.11**	107.44	**79.11**	1.04	0.05	0.03	9.18
Std. Deviation	1.72	0.37	0.97	40.79	0.10	0.07	1.98	19.60	16.62	0.39	0.07	0.02	3.34

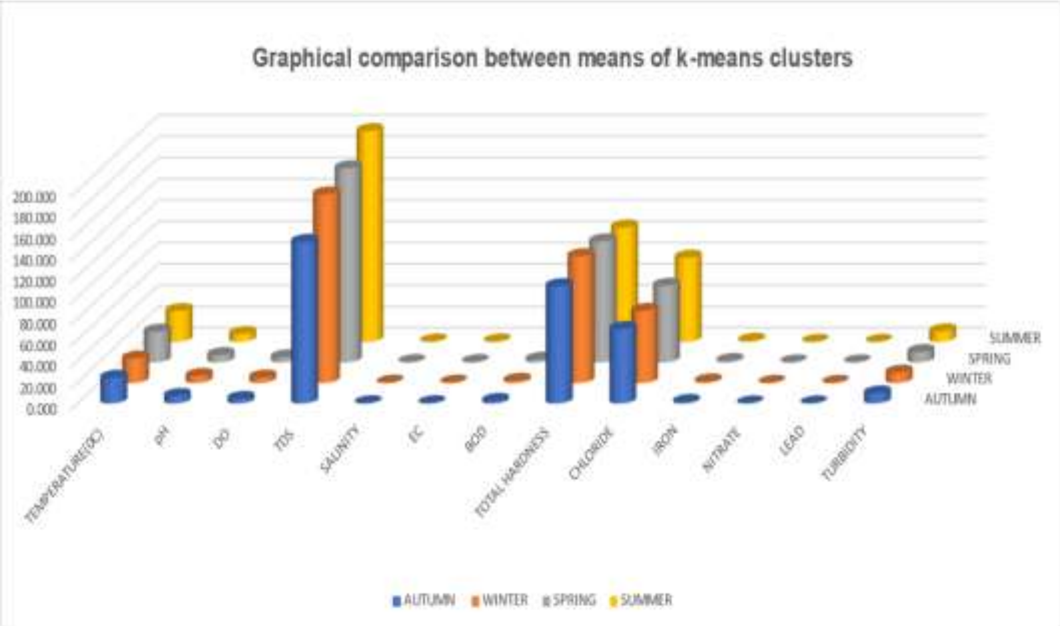

Fig 3.1.9 : Graphical comparison between means of k-means clusters

WATER QUALITY INDEX

Water quality index indicate single number like a grade that express overall water quality index at certain area and time. It gives general idea of the possible problem with water in a particular region to public.

Calculation of WQI by Weighted Arithmetic Water Quality Index Method

Weighted arithmetic water quality index method classified the water quality according to the degree of purity by using the most commonly measured water quality variables. The methodhas been widely used by the various scientists and the calculation of WQI was made by using the following equation:

$WQI = \sum Q_i W_i / \sum W_i$

The quality rating scale (Q_i) for each parameter is calculated by using this expression:

$Q_i = 100[(V_i - V_o)/(S_i - V_o)]$

Where, V_i is estimated concentration of i^{th} parameter in the analysed water

V_o is the ideal value of this parameter in pure water $V_o = 0$ (except pH =7.0 and DO = 14.6 mg/l) S_i is recommended standard value of i^{th} parameter The unit weight (W_i) for each water quality parameter is calculated by using the following formula:

$W_i = K / S_i$

Where, K = proportionality constant and can also be calculated by using the following equation:

$K = 1/ \sum(1/S_i)$

The rating of water quality according to this WQI is given in table 3.1.6. Water Quality Rating as per Weighted Arithmetic Water Quality Index Method.

Table 3.1.6:Water Quality Rating as per Weighted Arithmetic Water Quality Index Method

WQI	RATING OF WATER QUALITY
0-25	excellent

25-50	good
51-75	poor
76-100	very poor
>100	Unsuitable for drinking purpose

Table 3.1.7: BIS Standards for Various Water Quality Parameters for Drinking Purpose

PARAMETERS	BIS STD (Sn)
P^H	8.5
DO (mg/l)	4
TDS (mg/l)	500
EC (ms/cm)	300
Biological Oxygen Demand (mg/l)	4
Total Hardness (mg/l)	300
Chloride (mg/l)	250
Iron (mg/l)	0.3
Nitrate (mg/l)	50
Lead (mg/l)	0.1
Turbidity(NTU)	5

Table 3.1.8: Weighted Arithmetic Water Quality Index Values

SEASONS	WQI								
	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 6	SITE 7	SITE 8	SITE 9
AUTUMN	96.89603 very poor	115.7944 Unfit for drinking	67.47171 poor	120.6387 Unfit for drinking	175.7699 Unfit for drinking	289.502 Unfit for drinking	359.5903 Unfit for drinking	105.6474 Unfit for drinking	114.1924 Unfit for drinking
WINTER	90.27361 very poor	91.03769 very poor	71.01401 poor	127.247 Unfit for drinking	167.7728 Unfit for drinking	278.5764 Unfit for drinking	300.3564 Unfit for drinking	103.6474 Unfit for drinking	112.6637 Unfit for drinking
SPRING	88.41897	83.66808	63.31935 poor	122.6486	138.2403	268.1226	279.811	92.57437	97.54277

	very poor	very poor		Unfit for drinking	Unfit for drinking	Unfit for drinking	Unfit for drinking	very poor	very poor
SUMMER	84.31387 very poor	86.85631 very poor	63.7212 poor	122.5272 Unfit for drinking	132.3957 Unfit for drinking	136.6602 Unfit for drinking	146.4376 Unfit for drinking	107.0158 Unfit for drinking	100.7608 Unfit for drinking

From the above table 3.1.8, it is seen that the Weighted Arithmetic WQI values of Deepor Beel ranges from 63.31 to 359.59. According to Weighted Arithmetic Water Quality Index values water sample of Site 7 i.e., Boragaon Dumping Site (ii) is most polluted among all the collected water sample, which falls under “Unfit for drinking” rating.

6. CONCLUSION:

In this study, multivariate statistical approaches were used to assess the water quality data collected from nine distinct sampling locations over a one year period in the Deepor Beel in order to assess the water's suitability for aquatic life as well as its seasonal variation of Physio-chemical parameters. From the Principal Component Analysis, we can predict the parameters which are affecting more and the parameters which are less effective. From the table 3.1.1, it is seen that pH, TDS, Salinity, EC , BOD ,Nitrate, Turbidity and Lead are strongly effective and DO & Chloride are less effective in autumn season. From the table 3.1.2, it is seen that pH, Salinity, EC, BOD, Iron, Nitrate, Turbidity and Lead are strongly effective in winter season. It is observed in the table 3.1.3, that pH, EC, BOD ,Iron, Nitrate, Turbidity and Lead are strongly effective and DO is less effective in spring season. From the table 3.1.4, it is seen that pH, TDS, EC, BOD, Iron and Nitrate are strongly effective and DO& Total Hardness are less effective in summer season. The Pearson Correlation Analysis shows that there is moderate correlation between the parameters due to changes in land use, mining and improper effluent discharge in the river. When parameters exhibit strong or moderate correlation, explicit numerical representation of the input and output parameters is almost impossible and WQI may not effectively characterize the quality of water. Therefore, it is vital to convert correlated parameters into uncorrelated parameters for efficient forecasting of water quality. PCA provides a suitable method to transform correlated parameters into uncorrelated parameters. From the K-Means analysis, spatial variability of the hydrochemistry among the seasons are shown. The first season Autumn (9 observations) exhibits higher concentration of nitrate(0.07mg/l) and lead(0.07mg/l) relative to other seasons. The nitrate concentration is under permissible limit (<45mg/l) but lead concentration seems to be beyond permissible limit (>0.01mg/l). The second season exhibits higher concentration of DO (5mg/l) which signifies lesser pollution in winter season. Total hardness is also found in higher concentration (119.11mg/l). As per BIS total hardness ranges between 60mg/l to 120mg/l are classified as soft water. The winter season also consumes higher concentration of iron (1.5mg/l) which goes beyond the permissible limit of iron (>0.3 mg/l). The third season i.e., spring season samples are highly loaded with EC concentration (0.29 mg/l) and turbidity (9.78 NTU). Lastly the summer season's samples are bringing highest pH level (7.34), TDS (198.06 mg/l), salinity (0.27 mg/l), BOD (3.11 mg/l) and chloride content (79.11 mg/l). The highest BOD concentration notifies the highest pollution in summer season among all the four seasons. From the WQI analysis, we have checked the quality of water in nine different sites for four seasons. Sites are showing different water quality index in different season. From the table 3.18, it is seen that some sites are performing very poorly in terms of quality throughout all seasons, whereas, the two sites (site 6 and site 7) from Boragaon Dumping Station show the water quality rating as "Unfit for Consumption", which means water samples collected from these sites are not usable for any purpose, not good even for aquatic life.The analyses and statistical tests conducted have resulted in the protection of the lake water only depending on the control of the amount and content of the fertilizers used in agriculture activities and the effect of pH changes on the aquatic ecosystem due to the sudden temperature changes as a result of changing the climate. A suggested solution to the problems is "best environmental practice" principle should be applied to minimize the out-of-source pollution and to efficiently use and control stocks of freshwater resources.

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