 doi:10.20944/preprints202109.0237.v1

Pearson's correlation and trend analysis for physico-chemical parameters of Mansagar Lake, Jaipur

Yuvraj Singh[1], Manish Kumar Jain[2]

[1]Research scholar, [2]Associate Professor
Department of Environmental Science and Engineering
Indian Institute of Technology (Indian School of Mines) Dhanbad
[1]Corresponding author: bharatyuvraj4@gmail.com

Abstract: The article reviews the constituent's physico-chemical parameters in the water of the Mansagar Lake of the Jaipur City. The water quality is also investigated using evaluated physico-chemical parameters with in-depth study of their distribution as per sample location-wise and season-wise. A detailed discussion on the associationship among parameters (pH, Conductivity, turbidity, dissolved Oxygen, chemical and Biochemical Oxygen demand, etc.) using the Pearson's analytical method is also presented. The strength of the article is the graphical presentation of evaluated physico-chemical parameters and the water quality indices for sample station-wise and the season-wise. To our best of understanding, first time such details have been clubbed together and discussion in brief for studied lake.

Keywords: Mansagar Lake, Physico-chemical parameters, Water quality investigation, Trend analysis, Pearson's correlation analysis.

Introduction:

Various processes and parameters are identified in past, which mainly affects the water quality of a lake such as inputs from rain, effects of erosion and the weathering of the crustal material apart from other sources of pollutants such as agricultural, industrial, and otherurban activities [1]. Fragile ecosystem for lakes can be ensured by controlling the human encroachment and possible sources of pollutants. Ever increasing human settlement, uncontrolled agricultural practices and use of non-scientific drainage systems accelerate the eutrophication process in the urban water bodies such as ponds, lakes, etc. [2-3], which results in excessive nutrient and growth of algae and fungi. Since last century, contamination contents particularly for the Indian water bodies such as lakes, ponds, rivers, dam etc. have been noticed with growing trends, which are mainly caused by dense population, illegal settlements, eutrophication and the silt deposition, etc. [4-6]. Jaipur is one of the Indian cities, which are rich in heritage, cultural, forts, lakes and ancient structures. Due to its high cultural and heritage values, it attracts lots of tourists in almost all seasons and throughout the year. Among all tourist attractions; the Mansagar Lake popularly known as Jalmahal lake has its own and unique importance. However its water quality is at risk and has been subjected to various pollution sources; point and non-point sources [7].

Effluents from municipal facilities such as drain also leaddegradation in its water quality. Lack of proper planning in past had also been increasing the sedimentation of the pollutants, which resulting into the reduced water surface area and increase in the evaporation rate. This article explain the measurement of important constituent physico-chemical parameters such as pH, conductivity, turbidity, dissolved Oxygen (DO), chemical and Biochemical Oxygen demand (COD, BOD), total organic carbon (TOC), total dissolved solids (TDS) and Chloride. Distribution of these parameters as per sample, location-wise and environmental condition-wise are plotted to understand the water quality of the lake in

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 14 September 2021 doi:10.20944/preprints202109.0237.v1

depth. The water quality index (WQI) is one of the most effective tools to develop management strategies to control surface water pollution [8-10]. Some of the dominant parameters evaluated were then used to determine the WQI for the studied Jalmahal (Mansagar) lake and the results are plotted to check their distribution profile as per the prevailing and other external environmental situations. The correlation analysis among the physico-chemical parameters for a water body is a bivariate analysis, which defines the strength and direction of association between two parameters. The Pearson's correlation is a method of covariance, it is considered as the best method to measure the association between two continuous variables [11]. In the later part of the article, we have also outlined the calculated associationship among evaluated physico-chemical parameters with use of Pearson's correlation method concepts.

Study Area: The Mansagar (Jalmahal) Lake, Jaipur

The Mansagar Lake is located in the northwest part of the city with a palace in the middle; the Jalmahal built by Mansingh (I), in the year 1610. The Lake is located in the middle surrounding three hills and was constructed by building a dam over a river; the Dravawati, to address the drought in the surrounding lands [12]. During post-independence era, especially in the year 1962, the city administration diverted the sewage disposal of two large drainstowards the lake and from that stage the situation started getting worst for the fresh water source of the Pink city [12-14]. The dimension of the lake can be classified as the water surface area about 139 hectares and the catchment area of 23.5 sq. km with an average depth ranging 1.5m to 4.5m. Nearly half of its catchment area located near to dense urban area and the remaining area is covered by denuded hills. Due to discharge of organic waste the aquatic weeds started growing over the lake, which suppresses the aquatic life in the lake.

In view of maintaining its heritage value, year 1999 onwards, the responsible Government agencies started taking strict action for the revival of the Jalmahal region. The present status of the lake is much better as it has been developed into a tourist attraction as shown in the figure 1(a). However with increasing tourist activities, the lake front has been fuelled with solid waste and bread crum feeding since long. Also mixing of waste food, paper and plastic in the lake have been a challenging issue for management of the lake since long. The ground water sources near to the lake have been found affected with severe contaminations caused by mixing of untreated sewage water with the lake since long. Therefore, most of nearby water sources are unfit for their use as drinking source and posing serious health hazard to living beings. Moreover, situation becomes worse during rainy seasons, when the excess rain water flow into the lake with mingled with the pollution contents from adjoining rough areas and the roads.

For our study, we have selected the samples collection station on the basis of anthropologicalactivities around the lake, and the surroundings. After a detailed study on previous water quality report and the restoration works done in past, eleven important sites were chosen to collect and monitor the water quality for two applicable seasons (Pre- and Post-monsoon). As shown in the figure 1(b), the stations from L_1 to L_5 were chosen at the edge of the lake, while the stations from L_6 to L_{11} were across its width in almost in the centre. To analysis the water quality assessment of the studied lake, rigorous efforts have been placed to evaluate important physico-chemical parameters for its water. Standard procedures for sample collection and evaluation of physico-chemical parameters have been applied as discussed in our previous work [14]. As part of exercises, many roundsphysical and chemical tests were performed to calculate factors like pH, turbidity, DO, COD, BOD and many others.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 14 September 2021 doi:10.20944/preprints202109.0237.v1

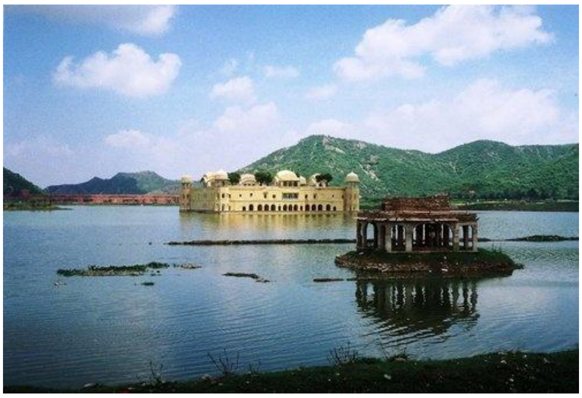


Fig. 1 (a) the panoramic view of Mansagar Lake, courtesy: https://www.jaipurcityblog.com (b) the sample stations, courtesy https://www.google.com/maps/@26.9554737,75.8470802,16z.

Evaluation and distribution plots of Physico-chemical parameters and metal constituents:

In this section, we shall be discussing corresponding distribution plots as per sample locations and their maximum, minimum and mean values. Comparison of parameters evaluated for the samples taken from various locations of the Jalmahal (Mansagar) lake was done as prescribed in water act 1974 for Pre- and Post-Monsoon seasons and tabulated as depicted by table 1 and 2. From these tables, it is clear that for post-monsoon days, evaluated pH values have been found in variation from 7.58–8.46 (pH unit) for stations at the edges and in the range of 8.59– 8.84 at the central (across the width) stations with mean values of 8.0 and 8.7 respectively.The pH values are relatively consistent at most of the central stations, while lowest and highest values were noticed at Station L_2 and L_{11}, respectively. On the other hand, the pH value of the lake has been found 8.22 – 8.87 during the pre-monsoon season with anaverage value of 8.70. The water is conductive in nature due to generation of the ions by salty and inorganic contents, which may increase if electrolytes are added [15-17]. The conductivity for the Mansagar lake water found to be in higher ranges, which indicate excess clay and limestone mixing with the lake from the surrounding hills. With our study, the conductivity of the lake water remains in the range 1019 µS/cm– 1477 µS/cm with a mean value; 1291.64 µS/cm for samples collected post-monsoon days. Also reason for conductivity may remains at higher levels during the pre-monsoon days due to extreme temperature and huge evaporation process in peak summers. The observed conductivity range was 1650 µS/cm– 1890 µS/cm with a mean value; 1763.64 µS/cm for samples collected pre-monsoon days, which actually correlate its values with impact of varied environmental conditions.

Table 1Evaluated physico-chemical parameters for the lake water (Pre- and Post-Monsoon seasons)

Sample Locations	pH (pH unit)		Conductivity (µS/cm)		Turbidity (NTU)		TDS (mg/L)	
	Pre-M	Post-M	Pre-M	Post-M	Pre-M	Post-M	Pre-M	Post-M
St.-L_1	8.58	7.58	1700	1070	3.0	7.3	1575	1776
St.-L_2	8.79	7.45	1650	1137	3.4	5.6	1554	1728
St.-L_3	8.42	8.57	1810	1472	2.2	8.2	1710	1968
St.-L_4	8.72	7.95	1750	1359	2.9	8.2	1625	1776
St.-L_5	8.78	8.46	1740	1019	2.4	5.2	1855	2064
St.-L_6	8.22	8.59	1780	1473	2.8	3.2	1710	1840
St.-L_7	8.87	8.63	1830	1373	2.7	3.2	1730	1824
St.-L_8	8.85	8.78	1890	1477	2.1	2.5	1745	1810
St.-L_9	8.82	8.62	1810	1412	2.2	2.8	1718	1824
St.-L_{10}	8.87	8.78	1760	1217	2.2	2.5	1732	1850
St.-L_{11}	8.86	8.84	1680	1199	2.3	2.8	1722	1824

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 14 September 2021 doi:10.20944/preprints202109.0237.v1

Table 2Evaluated physico-chemical parameters for the lake water (Pre- and Post-Monsoon seasons)

Sample Locations	COD (mg/L)		DO (mg/L or ppm)		BOD (mg/L)		TOC (mg/L or ppm)		Chloride (mg/L)	
	Pre-M	*Post-M*	*Pre-M*	*Post-M*	*Pre-M*	*Post-M*	*Pre-M*	*Post-M*	*Pre-M*	*Post-M*
St.-L_1	260.5	340.5	2.8	1.6	8.0	20	410.0	328.8	452.35	139.95
St.-L_2	300.8	370.3	3.5	1.9	9.0	21	455.2	392.9	457.35	149.95
St.-L_3	380.2	459.0	3.5	2.5	8.0	22	390.5	359.2	354.95	149.95
St.-L_4	360.0	245.4	5.3	4.5	10	22	395.0	341.6	439.86	144.98
St.-L_5	240.9	241.6	4.7	4.4	14	18	410.5	340.4	442.36	144.95
St.-L_6	247.6	280.1	2.7	1.8	13	14	460.5	360.2	379.94	134.95
St.-L_7	270.2	320.0	3.5	3.0	9.0	14	380.5	339.0	357.55	109.96
St.-L_8	230.5	244.0	2.9	2.5	7.0	12	410.8	334.5	310.20	140.00
St.-L_9	267.8	316.7	3.0	2.3	8.0	12	435.0	350.6	339.30	141.40
St.-L_{10}	320.6	544.5	2.8	1.7	8.0	14	470.9	345.5	360.10	139.45
St.-L_{11}	280.8	311.2	2.6	1.8	11	16	425.5	330.8	315.50	132.35

The relative clarity of a water body can be measured in terms of turbidity. Highly turbid water scatters more sun light, and may contain particles, which are not good for human consumption.The particle can be added from any source like various discharges of water streams, storms, soil erosions etc. The increase in turbidity increases risk of flood, affects water clarity and its use for habitat. It is determined by the amount of scattering light of the suspended. We have evaluated the turbidity values for samples collected during peak summers (Pre-monsoon season) and observed its values varied in the range from 2.1–3.4 (NTU) with a mean value; 2.56 NTU. Increased levels of turbidity were observed for post-monsoon days mainly mixing of particles by rainy water from nearby surfaces and paved roads. The surface turbidity value was observed in varied range from 5.2–8.2 (NTU) for stations at the edges and in the range of 2.5–3.2 (NTU) at the central (across the width) stations with mean values of 6.9 NTU and 2.83 NTU respectively. The observed values of turbidity increase significantly as depth increased at all stations which agree with the previous studies for this lake.It is also worthy to mention here that visitor's movement nearby to the Stations L_3 and L_4causes more turbid water in these locations. However with recent efforts made by the City municipal agencies, improvements in the turbidity have also been noticed as compared to previous studies.

Solids can be categorized as suspended, volatile and dissolve. Suspended solid generally results from effluents from sewage discharge, dead plants and slits. Many factors such as fertilizers, organic matter and dissolving salty particles affectsquantity of Total dissolved solids (TDS) and quality of the aquatic life of a lake. Typical favorable TDS values in fresh water bodies should be in the range of 50 to 250 mg/L, however permitted with higher range; 1000-1500 mg/L in specific regions containing the high saline water and presence of others minerals. However, with our study, observed TDS values were in a higher range; 1500 mg/L -2000 mg/L. Figure 1 summarizes evaluated values for pH, turbidity, TDS and conductivity in a graphical manner for varied environmental conditions (pre- and post-monsoon). These plots are prepared for data visualization with use of trend line connecting the values obtained for a variable (along the y–axis) with respected to the number of tested samples (along the x–axis). The COD gives the quantity of organic compounds in the lake and is expressed in mg/l. It also measures the oxidizable pollutants in water. As per most of environmental reports released in past on the water quality, the maximum permissible value of the COD is 250 mg/L for lakes with fresh water suitable for aquatic life. As indicated by table 2, the COD values have been found in variation from 241.6mg/L – 459 mg/L and in the range of 230.5mg/L –380.2mg/L with mean values of 333.93 mg/L and 287.26 mg/L for post-monsoon and pre-monsoon seasons respectively. Observed high values of COD indicate excess mixing of the organic waste from local and polluted streams. We also observed that the COD of samples taken the Mansagar Lake exceeded the limit in most cases. Perhaps, the illegal garbage dumping, leaked sewage, rain runoff and waste discharges from the tourist and locals results in high valued COD in post-monsoon days as well, while rainy days causes inflow of organic streams in to the lake.

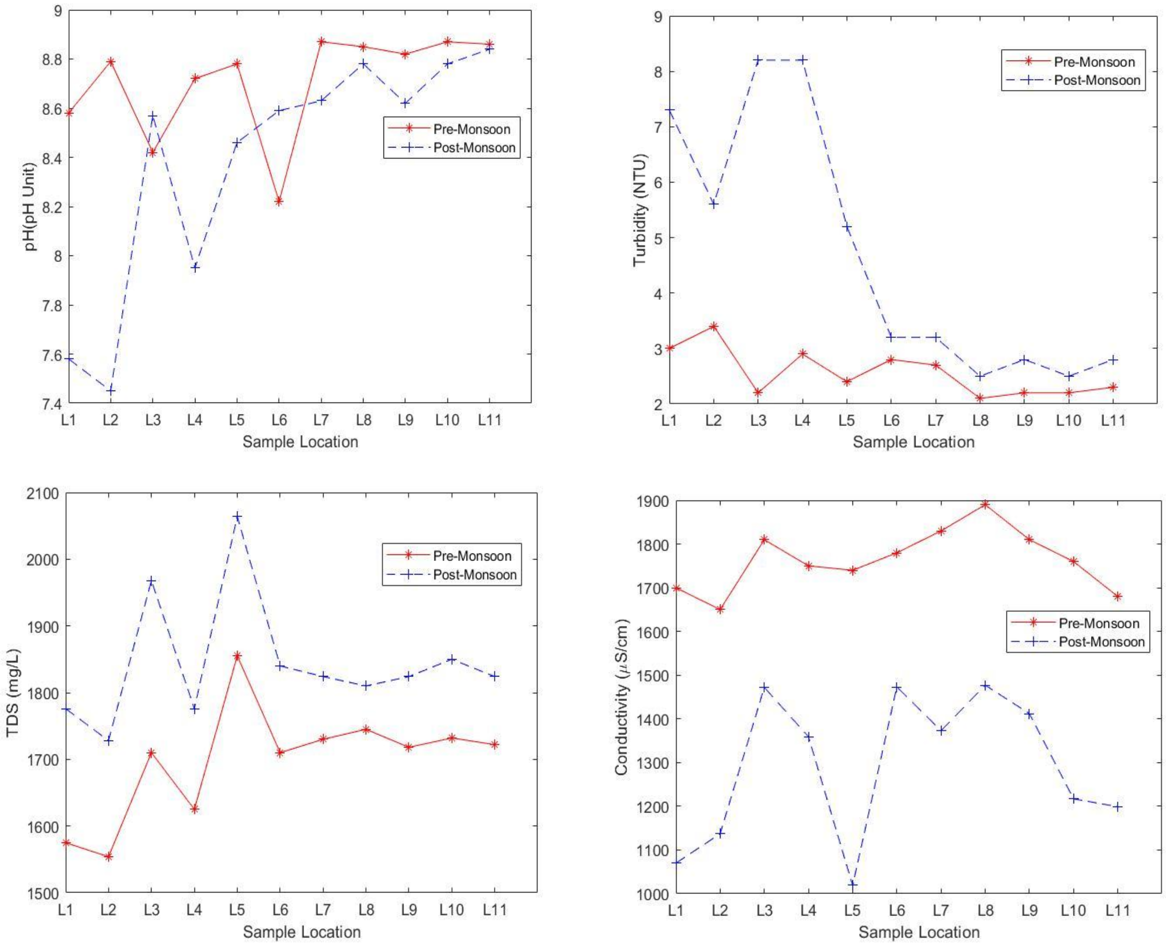


Fig. 2 The distribution plots for evaluated pH, turbidity, TDS and conductivity

It shows the increase in the pollutants due to mixing of the waste from visitors, increased household wastewater and waste discharges. The DOlevels indicate the aquatic quality of the lake and its minimum accepted value must be in the range 4 mg/L –5 mg/L to supportlarge population of fishes. Also its value should not be below 3 mg/L for survival of the aquatic life. The DO levels have been found in a wider range; 1.6mg/L to 4.5mg/L with an average value; 2.54 and in the range of 2.6 mg/L to 5.3 mg/L with a mean value; 3.4 mg/L for samples collected post- and pre-monsoon seasons respectively. Also, these DO levels does not comply with WHO standards and cannot be consider safe for human consumption and is at the level of danger for most aquatic biota including the fish populations. The healthy level of DO content above 4.5 mg/L was only observed at stations; L_4 and L_5 in the lake. The Oxygen is consumed by bacteria and other microorganisms during their organic matter decomposition process. The amount of consumed Oxygen can be measured in terms of the BOD. In fresh water bodies, the BOD values should be on the lower side of the scale, a higher value than 20 mg/L contribute pollution in the water. The higher the decomposable matter in the lake more is the value of BOD. Indeed, the higher value of the BOD also affects the dissolved oxygen values available for aquatic habitat, which suppresses DO levels. Seasonal variation from dry to wet condition show upward trend at all sites for the studied lake. The regional distribution of BOD in the studied lake varied between 12.0 mg/L to 22 mg/L and in the range 8.0 mg/L to 14.0 mg/L during post- and pre monsoon days respectively. The seasonal average concentration of BOD in the lake

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 14 September 2021 doi:10.20944/preprints202109.0237.v1

found to be fluctuated with values of 20.6 mg/L and 9.8 mg/L at the edges and 14.0 mg/L and 11.2 mg/L at stations taken across width (middle) of the lake during post- and pre-monsoon days respectively. Figure 3 represent levels for COD, DO and BOD parameters graphically for pre- and post-monsoon sampling. The high BOD concentrations at the most of the stations located at the edges of the lake has been due to the ongoing fencing restoration works and logging activities, which causes loading of the organic matters from the anthropogenic activities.

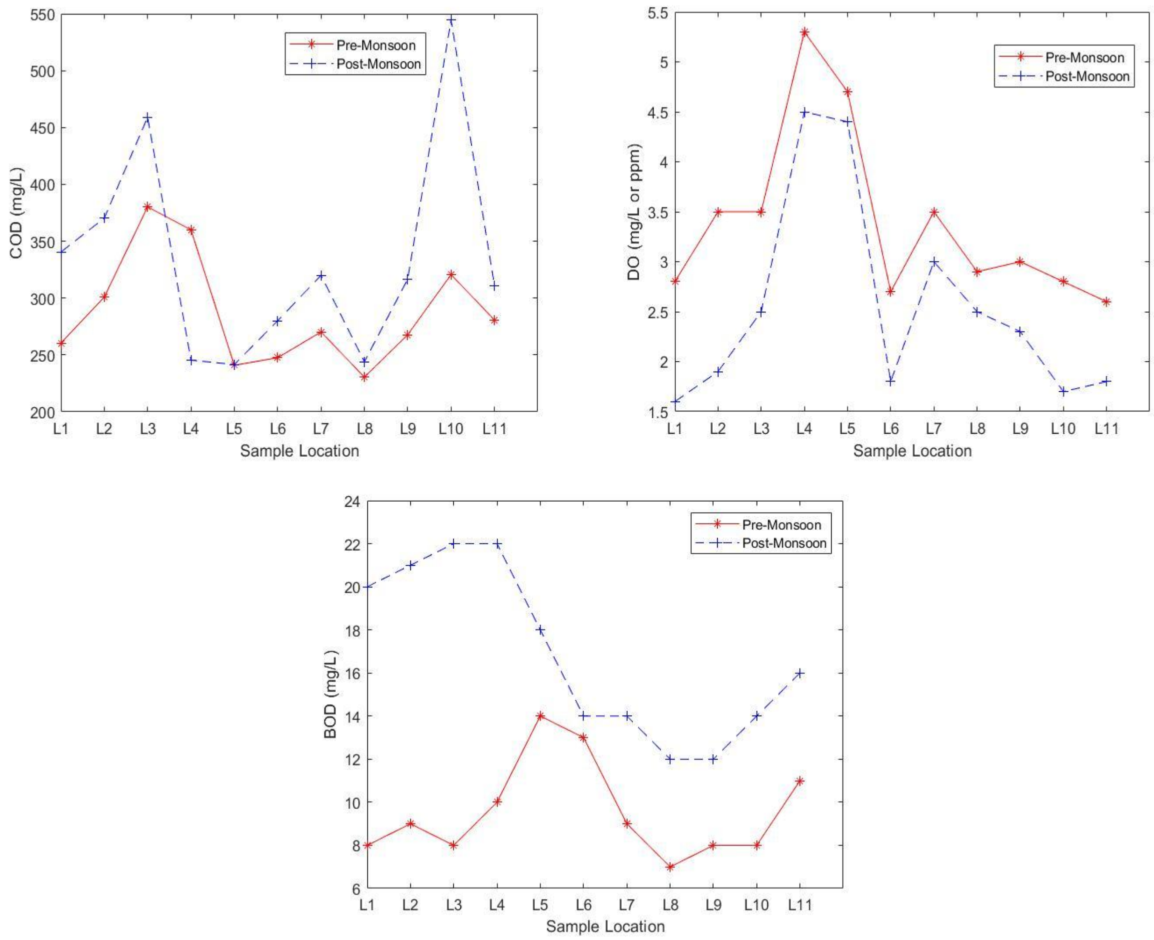
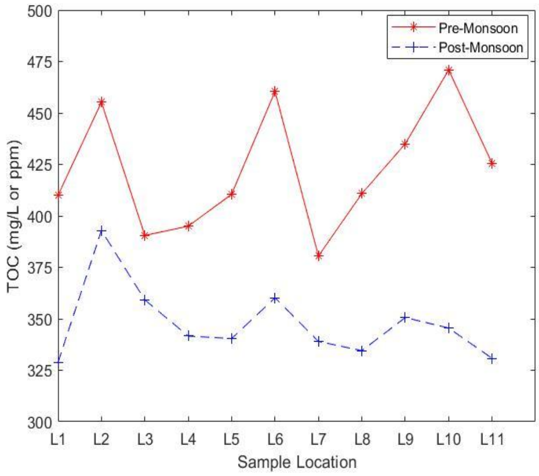


Fig. 3: The distribution plots for evaluated COD, DO and BOD parameters

Total organic carbon (TOC) is often used to classify the water quality of lakes and measure the quantity of carbon in organic compounds usually expressed in mg/L or PPM. Typically, the TOC levels are found in range; 300 – 500 (ppm/mg/L) depending upon the source of the water such as sea, ground or waste water. With our rigorous observations, we noticed elevated TOC contents mainly causing from lake borne plants and stray animals, which can be used to define the productivity [18-19]. As indicated by the table 2, the distribution of TOC levels in the studied lake varied between 380.5.0 mg/L to 470.9 mg/L and 328.8 mg/L to 392.9 mg/L during pre- and post-monsoon days respectively. We also noticed that, the presence of the carbon contents was in three forms; elemental, inorganic and organic. The analytical description of the TOC can be used as a biomarker to reconstruct the depositional environment for sedimentation, and can interpret its previous environmental changes. Chlorides are found in all major water sources; it is a corrosive agent and higher values of chloride are dangerous for the infrastructures. The chlorides contents in the samples were observed in varied range; such as 139.95 mg/L – 149.95 mg/L for stations at the edges and in the range; 109.96 mg/L – 141.40 mg/L at the central (across the width) stations with mean values of 146 mg/L and 131.6 mg/L respectively during post-monsoon days. However, the Chloride contents has been found significantly in high in the range 310.20 mg/L – 457.35

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 14 September 2021 doi:10.20944/preprints202109.0237.v1

mg/L during pre-monsoon days (dry season) with an average value of 382.68 mg/L. During dry season, high Chloride contents indicate additional presence of organic pollutants caused by increased domestic pollution activities. The non point streams of sewage, fertilizers and road ran off are major threat. It was noticed that elevation in the Chloride concentrations in the lake water may take place due to road ran off and remain with increasing trends during pre-monsoon days. Such imbalance creates risk for nearby infrastructures as well as aquatic to ecosystems in future. The plots depicted by figure 4, can be used to understand variation in the TOC and Chloride contents with respect environmental conditions and the sample locations.



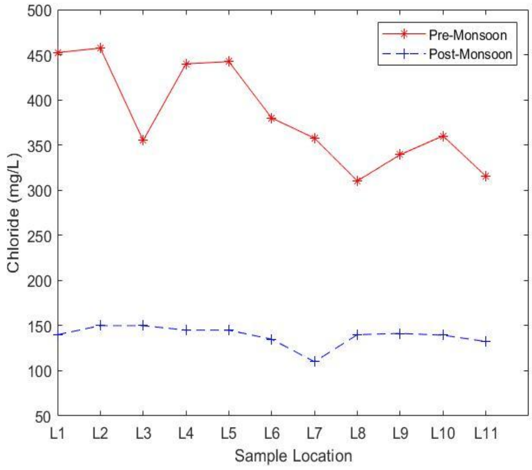


Fig. 4: The distribution plots for evaluated TOC and Chloride contents.

It is quite clear from the trends depicted by figures 2 to 4, that variation in few parameters such as (Turbidity DO, BOD, TOC) are of linear nature w.r.t the environmental conditions and sample locations, while trends for other parameters are non-linear, as the variations are random irrespective of station locations. COD levels varies mainly in nonlinear fashion and somewhat unpredictable in nature w.r.t the sample locations. These plots are good enough to establish the correlation among evaluated parameters and visualize the data and the distribution information in the lake water. We have also prepared the data table for maximum, minimum and mean values for pre- and post-monsoon seasons for evaluated physico-chemical parameters and were plotted as shown by the figures 5 and 6.

 doi:10.20944/preprints202109.0237.v1

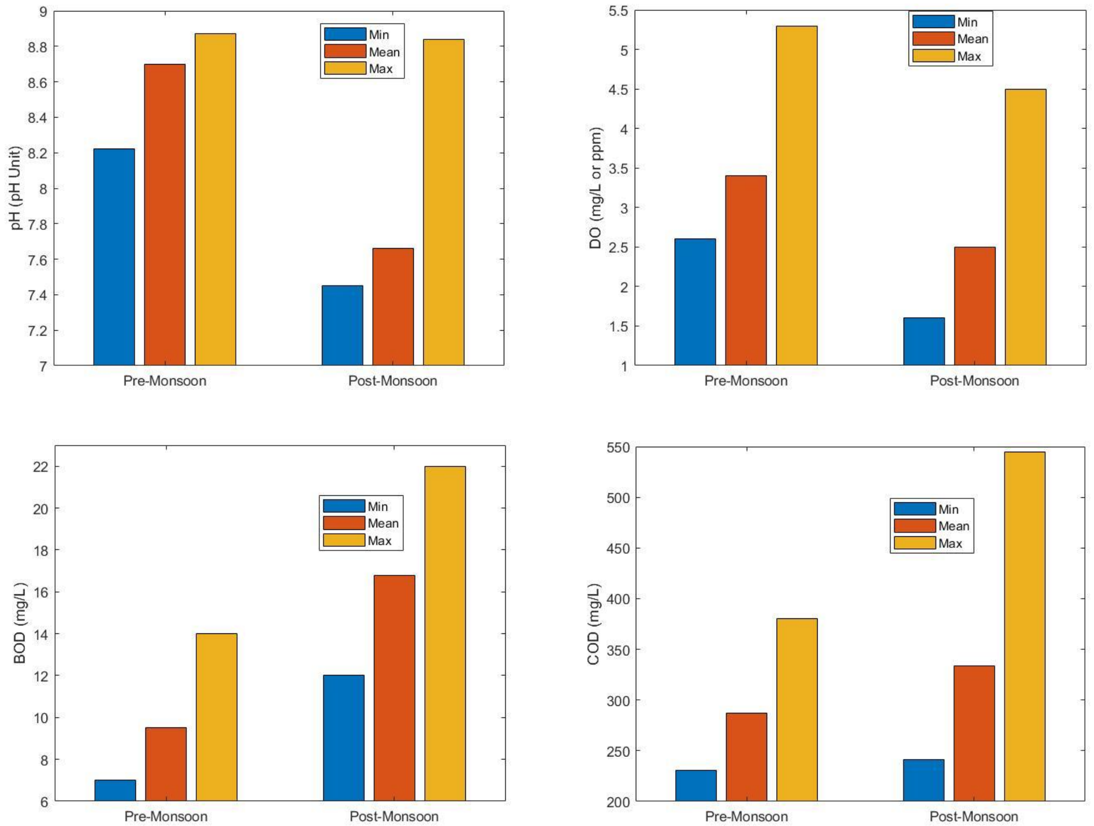
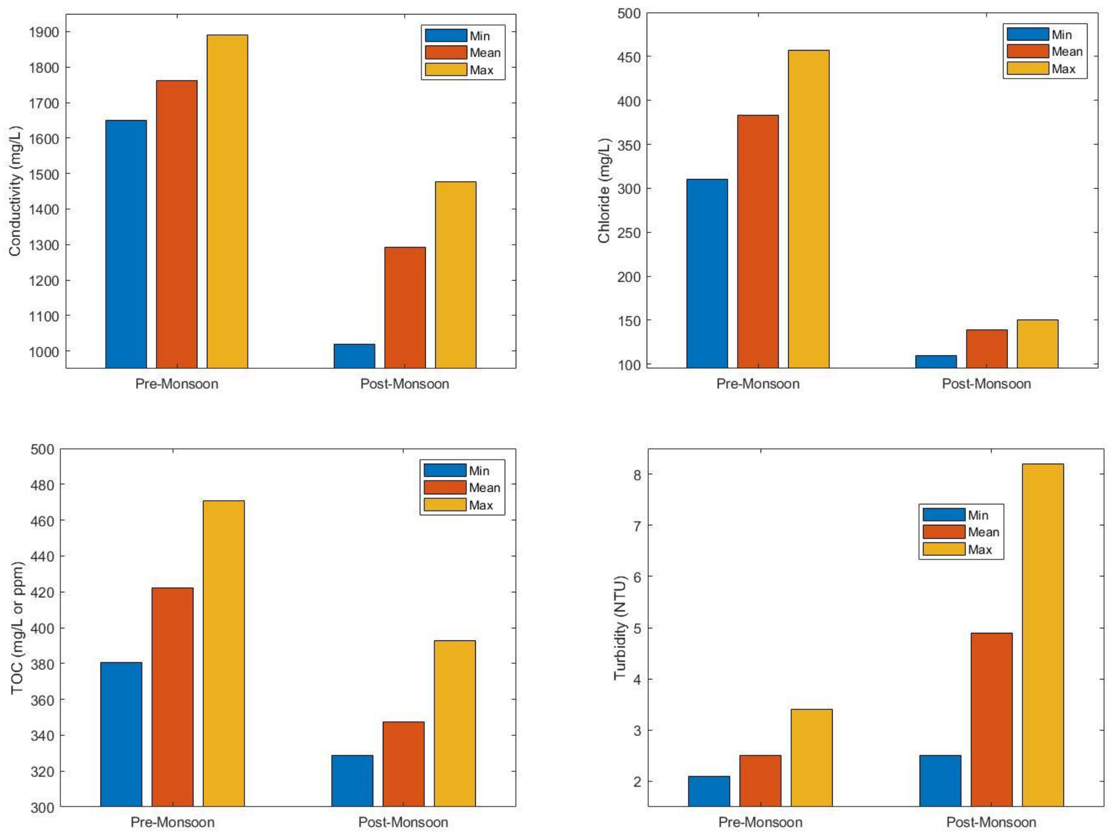


Fig.5 The bar charts depicting maximum, minimum and mean values of evaluated parameters (pH, DO, BOD and COD) season wise.



Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 14 September 2021 doi:10.20944/preprints202109.0237.v1

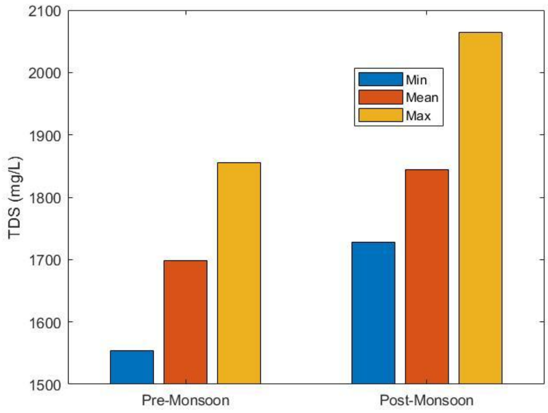


Fig. 6 The bar charts depicting maximum, minimum and mean values of evaluated parameters (conductivity, chloride, TOC turbidity and TDS) season wise.

Water quality index determination:

The water quality index indicates the value of water quality at a specific location and time based on the single value of selected variable [19]. In our study, the objective to estimate the water quality index at sample locations was to represent the complex data into the water quality information, which is easy to understand and usable by the public and reader of this work. Although water quality represented by a single number cannot tell about complete story of the water quality; there were many other water quality parameters, which were not included in calculating the index. In general, use of important parameters such as temperature, DO, pH, COD, TDS, BOD, turbidity, etc. have been in practice to estimate the water quality index [20-27]. The water quality index is based on the level of the water quality (Q) and weigh factor (w) that gives the relative importance of a parameter with overall quality. The WQI based on certain important quality parameters can indicate quality of the water as per range shown in the table 3. Water quality index was calculated by using the weighted arithmetic index method as described by *Curtis G. Cude, 2001* [25].

Table 3: Water quality index scale

Water quality	WQI Values; Ref. [20-26]
Excellent	Less than 50
Good	50–100
Poor	100–200
Very Poor (bad quality water)	200–300
Not suitable for drinking and aquatic life	More than 300

In last one decade, many researchers such as *Dirisu A.R. et al.* and *Ahmad I. Khwakaram et al.* [21-22] have modified this method in which various water quality factors are multiplies with a weighting factor and then calculated by taking arithmetic means in the process of calculating the water quality first the quality rating using following equation [21-25];

$$Q_i = (V_o - V_{id})/(V_s - V_{id}) \times 100 \quad (1)$$

In this Q_i is the quality rating of i^{th} parameter for n water quality parameters, V_o is the actual value of the water quality parameter obtained from analysis and V_s is the recommended standard value. While the V_{id} is the ideal value of that water quality parameter, which has been referenced from the standard tables; for example, the V_{id} for pH is 7 and for other

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 14 September 2021 doi:10.20944/preprints202109.0237.v1

parameters it equals to zero, and for the dissolved oxygen, the V_{id} is 14.6 mg/L. Thereafter, the relative value of weight was determined by the relation $W_i = I/S_i$, where W_i is the nth, S_i is the value of permissible standard for n^{th} parameter and the I is the proportionality constant and taken as; 1.8615. The overall water quality index can be determined by aggregating rating of quality with weight using below mentioned equation [21-25]:

$$WQI = \sum Q_i W_i / \sum W_i \quad (2)$$

Where, Q_i is the quality rating and W_i is the relative (unit) weight. The relative unit weight W_i values for each parameter are considered as pet table 4.

Table 4: Water parameters standards and unit weights as per recommending agencies and literatures (All values except pH are in mg/L), Ref. [28-33]

Parameter	Standard Value	Recommended Agency	Calculated Unit Weight
pH	6.5-8.5	BIS:10500: 2012	0.2190
Turbidity	1.0-5.0	BIS:10500: 2012, Ref. [30-31]	0.3723
TDS	500-2000	BIS:10500: 2012	0.0009
BOD	5.0	ICMR/BIS:10500: 2012	0.3723
DO	5.0	ICMR/BIS:10500: 2012	0.3723
TOC	300	Ref. [32]	0.0062
CL	250-1000	BIS:10500: 2012	0.0019

In our study, the WQI levels were categorized based on permissibility for human consumption or uses and the standard value of maximum permissible WQI value for domestic uses. We also aimed for assessing the surface water WQI for all chosen sample locations by monitoring and evaluating collected samples for varied environmental conditions. The mean valued data have been used subsequently for calculation of WQI using mean arithmetic methods. We preferred to calculate the WQI values using dominant parameters only such as pH, turbidity, TDS, BOD, DO, TOC, and chlorides contents. Table 5 depicts calculated WQI values for samples collected duringpre- and post-monsoon days for chosen locations; L_1-L_{11}. As reported earlier, these strategic locations were chosen on the basis of availability of water for testing, which constitutes possible contamination and mixing of water contents from treatment plant and the major effluents inlets. From table 5, it is clear that the WQI values remain high sample collected from most locations during post-monsoon days.

Table 5: Comparative WQI values for pre- and post-monsoon seasons

Station	Calculated WQI Value		
	Pre-Monsoon	Post-Monsoon	Mean-Value
L_1	112.83	195.52	154.17
L_2	120.75	189.45	155.10
L_3	104.59	219.75	162.17
L_4	117.62	207.22	162.42
L_5	139.40	174.31	156.85
L_6	135.82	150.01	142.91
L_7	117.76	146.95	132.35
L_8	104.92	135.08	120.00
L_9	110.45	135.59	123.02
L_{10}	111.63	148.47	130.05
L_{11}	129.17	161.54	145.35

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 14 September 2021 doi:10.20944/preprints202109.0237.v1

The WQI values for stations; L_1 to L_{11} were found in the ranges; 104.59 – 135.82 and 135.08 – 219.75 for pre- and post-monsoon days of investigations. Further, it is apparent from obtained WQI values, that the studied lake water quality belongs to poor to very poor water quality classification during post-monsoon days, while the quality belongs to moderate to poor water classifications during pre-monsoon days.Also, high WQI values for test sample collected from L_1 and L_4 locations indicates more deteriorated quality of the water. These locations are near to the inlets, where from the domestic garbage and contaminations are mixing with the lake water.Reasons for spikes in WQI values for some stations are due to state agencies yearly lake management process, which reduces quantity of the pollutants and contamination concentration in the lake water.We have further analyzed the values obtained for WQI levels and prepare the data table showing the mean values station wise. For better understanding the trends w.r.t to the environmental conditions, bar and curved line charts were obtained as shown by the figure 7. With this work, we focused on demonstrating the WQI values describing the spatial and temporal water quality information. The calculated WQI values may be use to enhance the quality of water body and to narrate requisite concrete planning for restoration of the lake. The evaluated WQI values can be set as a benchmark for easy understanding of overall water quality and the water management techniques to be adopted for taken care of its water quality.

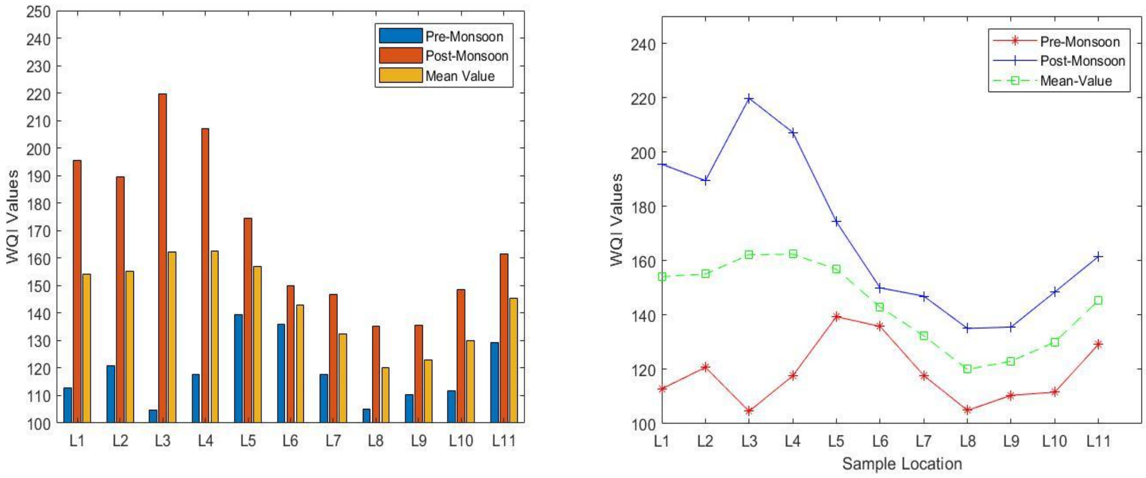


Fig. 7: Graphical representation (a) bar chart and (b) curved lines WQI distribution season- and station-wise

The water quality ratings at most of the sampling sites indicate clearly that the quality of the lake water has been degrading. Since the evaluated WQI values are not in acceptable range as described by the WHO standards and guidelines, the lake water cannot be recommended for its uses for domestic and drinking purposes. It was also observed that the pollution load was relatively high post-monsoon days/months as compared to the pre-monsoon season. We also conclude that, discharges from of nearby domestic and industry applicants and ever-increasing anthropogenic activities are primary concerns, thereby regular monitoring for Mansagar Lake is recommended.

Pearson's correlation analysis:

The Pearson's correlation coefficient; '*r*' is the mathematical correlation coefficientthat measures the strength of statistical relationship, or association between two continuous variables on the same interval or ratio scale and can be calculated by [34];

$$r = \frac{\sum_i (xi - x')(yi - y')}{\sqrt{\sum_i (xi - x')^{\wedge}2}\sqrt{\sum_i (yi - y')^{\wedge}2}} \quad (3)$$

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 14 September 2021 doi:10.20944/preprints202109.0237.v1

Where 'x_i' and 'y_i' is values of x- and y-variables in a sample, whereas x' and y' are mean values of x- and y-variables. Range of Pearson coefficient is from +1 to -1. Using the coefficient value, we calculate predict the linearity among the parameters. The strength of association should be higher as the resemblance to a straight line comes closer. If the value of Pearson coefficient takes values equal to +1, -1 or zero, the relationship between two variables can be defined as perfectly positive, negative or no correlation respectively [35]. Apart from these levels of correlation factor, there are many intermediate stages/levels, which have been used to define relationship among the parameters with more details. The table 6 depicts the interpretations for different values of the Pearson's correlation coefficient (r), as described by *Haldun Akoglu, 2018* [36].

Table 6: Interpretation of the Pearson's correlation coefficients, Ref. [36]

'r' value	*Associationship/Correlation level*
+0.70 ≤ n	Very strong positive relationship
+0.40 ≤ +0.69	Strong positive relationship
+0.30 ≤ +0.39	Moderate positive relationship
+0.20 ≤ +0.29	weak positive relationship
+0.01 ≤ +0.19	No or negligible relationship
0	No relationship [zero correlation]
-0.01 ≥ -0.19	No or negligible relationship
-0.20 ≥ -0.29	weak negative relationship
-0.30 ≥ -0.39	Moderate negative relationship
-0.40 ≥ -0.69	Strong negative relationship
-0.70 ≥ n	Very strong negative relationship

Other important characteristic of the Pearson' coefficient, that it represents a pure number means, it has different measurements unit as it is independent of the unit of measurement. Also, it possesses similarity properties means, the correlation of the coefficient between two variables are similar in nature i.e., the coefficient value will remain same between x and y or y and x [11], [37]. These concepts have been used to determine the Pearson's correlation coefficient ('r') among the laboratory measured important physico-chemical parameters with use of equation 3. The tables 7 and 8 represent the Correlation table (Pearson's method) for evaluated physico-chemical parameters from the samples (stations: $L_1 – L_{11}$) for post- and pre monsoon seasons respectively. Evaluated Pearson correlation matrices can be interpreted to establish relationship between different parameters linearly in either positive or negative way. For simplicity, we have evaluated the correlation coefficient 'r' up to two decimal values only.

Table 7: Correlation table (Pearson's method) for evaluated physico-chemical parameters; Post-Monsoon season (Stations: $L_1 – L_{11}$)

	pH	Conductivity	Turbidity	TDS	COD	DO	BOD	TOC	Chloride
pH	1								
Conductivity	0.47	1							
Turbidity	-0.66	-0.17	1						
TDS	0.43	-0.12	0.09	1					
COD	0.07	-0.05	0.02	0.02	1				
DO	-0.03	-0.04	0.37	0.43	-0.50	1			
BOD	-0.70	-0.35	0.93	0.05	0.10	0.29	1		
TOC	-0.40	0.07	0.15	-0.17	0.27	-0.20	0.29	1	
Chloride	-0.40	-0.17	0.50	0.15	0.14	0.07	0.52	0.41	1

Such matrices find wider application in water analysis if applied judiciously among different pollutants which are generally present in water. From table 7, it is clear that the evaluated Pearson correlation coefficient 'r' for post-monsoon days, indicate very strong positive association between BOD and turbidity (0.93), strong positive association between BOD and Chloride (0.51), TDS with DO and pH (0.43), and TOC and Chloride (0.41). On the other hand, the value of '*r*' indicates very strong negative relation between pH and BOD (-0.70), a strong negative relation between pH with turbidity, TOC and Chloride as -0.66, -0.40 and -0.40 respectively. On similar ways we can define the association between other parameters and for the table 6.3, which co-relates the parameters for evaluated samples of pre-monsoon days.

Table 8: Correlation table (Pearson's method) for evaluated physico-chemical parameters; Pre-Monsoon season (Stations: $L_1 - L_{11}$)

	pH	Conductivity	Turbidity	TDS	COD	DO	BOD	TOC	Chloride
pH	1								
Conductivity	-0.03	1							
Turbidity	-0.21	-0.60	1						
TDS	0.16	0.49	-0.75	1					
COD	-0.13	-0.14	0.05	-0.32	1				
DO	0.10	-0.07	0.24	0.07	0.36	1			
BOD	-0.30	-0.32	0.16	0.41	-0.27	0.33	1		
TOC	-0.08	-0.34	0.10	-0.11	-0.17	-0.47	0.12	1	
Chloride	-0.18	-0.60	0.78	-0.47	0.12	0.56	0.30	0.01	1

By comparing and co-relating the values of '*r*' from table 7 and 8, it is clear that the associationship between the turbidity and Chlorides remain equals or above strong positive irrespective of changes in the environmental conditions. Similarly, the association of pH with major parameters such as turbidity, BOD, DO, TOC and Chloride remains negative in nature (strong to week), while the association of turbidity with major parameters such as COD, BOD, DO, TOC and Chloride remains positive in nature (very strong to week).Also, the relation of BOD with TOC and Chloride remains positive (negligible to strong associationship). Many other observations can be made by comparision of data tables 7 and 8 for station- and season-wise correlation among evaluated parameters.

Conclusion:

We have discussed trends of evaluated physico-chemical parameters with respect to the locations and season for the surface water of the Mansagar Lake. It has been noticed that the contaminations have been added in the lake by point sources and non point sources pollutant agents. The experimental outcomes for collected samples indicated that this lake have been vulnerable for sewage intake, waste dumping due to the pressure from the unplanned urban developmental works and increasing human population. The WQI values and the associationship among the physico-chemical parameters are explained to establish its water quality, whichmay useful for its ecological applications. The calculated parameters such as WQI, Pearson's correlation coefficients can be use to prepare scientific measures for better management of the lakes. Also these parameters may be utilized to formulate optimal network design for quality assured monitoring of water bodies.

Acknowledgement:

We are grateful to the ESE, IIT-ISM Dhanbad and the Department of Civil Engineering, MNIT Jaipur for providing necessary technical support, simulation tools and equipments for work. We also extend our thanks to the Government agencies associated with the Mansagar lake and adjoining areas for permitting us to carry out this study.

References:

[1] MarynaStrokal, ZhaohaiBai, WietseFranssen, *et al.*Urbanization: an increasing source of multiple pollutants to rivers in the 21st century. NPJ Urban Sustain 1: 24, https://doi.org/10.1038/s42949-021-00026-w, 2021
[2] Grochowska, J.; Tandyrak, R. The Influence of the Modernization of the City Sewage System on the External Load and Trophic State of the Kartuzy Lake Complex.Appl. Sci., 11, 974.https://doi.org/10.3390/app11030974, 2021.
[3] Dong-Kyun Kim, Cindy Yang, *et al.*Eutrophication management in a Great Lakes wetland: examination of the existence of alternative ecological states. Ecosphere, 12(2), https://doi.org/10.1002/ecs2.3339, 2021.
[4] Raman Vinna, L., Medhaug, I., Schmid, M., D. Bouffard. The vulnerability of lakes to climate change along an altitudinal gradient. Commun. Earth Environ. 2, 35.https://doi.org/10.1038/s43247-021-00106-w, 2021
[5] R. R. Surve, A. V. Shirke, R. R. Athalye, M. M. Sangare. A Review on Chemical and Ecological Status of Lonar Lake.Curr. World Environ.; 16(1), http://dx.doi.org/10.12944/CWE.16.1.07, 2021.
[6] MV Prasanna, S Chidambaram, TV Gireesh, TVJ Ali. A study on hydrochemical characteristics of surface and sub-surface water in and around Perumal Lake, Cuddalore district, Tamil Nadu, South India" Environ Earth Sci., 2010.
[7] Q Zhang, Z Li, G Zeng, J. Li *et al.* Assessment of surface water quality using multivariate statistical techniques in red soil hilly region: a case study of Xiangjiang watershed, China. Environ Monit Assess 152:123–131, 2009
[8] Khushbu K Birawat, Hymavathi, *et al.* Impact of urbanisation on lakes-a study of Bengaluru lakes through water quality index (WQI) and overall index of pollution (OIP). Environ Monit. Assess.,193(7):408, https://doi.org/10.1007/s10661-021-09131-w, 2021.
[9] Chanchal Kumar Mukherjee, Dr.BhagirathiTripathy, *et al.* Water Quality Assessment of Brahmani River at Talcher City, Odisha (A Case Study). IOSR Journal of Mechanical and Civil Engineering, 15(5): 25-33, https://doi.org/10.9790/1684-1505042533, 2018.
[10] Wu, Z., Zhang, D., Cai, *et al.* Water quality assessment based on the water quality index method in Lake Poyang: The largest freshwater lake in China. *Sci Rep* 7, 17999, https://doi.org/10.1038/s41598-017-18285-y, 2017.
[11] Puth, MT, Neuhauser, M &Ruxton, GD. Effective use of Pearson's product-moment correlation coefficient. Animal Behaviour, vol. 93, pp. 183-189. https://doi.org/10.1016/j.anbehav.2014.05.003, 2014.
[12] K. P. Sharma ,Subhasini Sharma, *et al.*Mansagar Lake: Past, Present & Future" Proceedings of Taal 2007, 1530-1541, 2007.
[13] ChetnaPradhan; Dr. Surendra Singh Chauhan.Mansagar Lake:- Study of the water and associated Soil Quality, by analyzing their various Physico-Chemical Parameters. International Journal of Scientific and Research Publications, ISSN 2250-3153 , 6(8), 2016.
[14] Yuvraj Singh, Manish Kumar Jain. Assessment of physico-chemical parameters and metal contents of Mansagar Lake of Jaipur" Environmental Earth Sciences, 80, Article number: 284, https://doi.org/10.1007/s12665-021-09576-9, 2021.
[15] Y Shuchun, X Bin, K Deyang. Chronology and nutrients change in recent sediment of Taihu Lake, lower Changjiang River Basin, East China. Chin Geogr. Sci. 20(3):202–208, https://doi.org/10.1007/s11769-010-0202-1, 2010.
[16] United State Environmental Protection Agency: US-EPA. Conductivity in Water: Monitoring and Assessment" Unit 5.9, 2012
[17] H. Perlman. Electrical Conductivity and Water" Report available with the USGS Water Science School, 2014.
[18] Y. Zhou, D. R. Obenour, D. Scavia, T. H. Johengen, and A. M. Michalak, "Spatial and temporal trends in Lake Erie hypoxia, 1987-2007," Environmental Science and Technology, vol. 47, no. 2, pp. 899–905, 2013, https://doi.org/10.1021/es303401b.
[19] J. J. Lowe,& M.J.C Walker. Reconstructing Quaternary Environments. 3rd edition, Routledge, ISBN 9780131274686, pages: 568, London, 2015.
[20] Das Kangabam, R., Bhoominathan, S.D., *et al.* Development of a water quality index (WQI) for the Loktak Lake in India. Appl Water Sci **7,** 2907–2918, https://doi.org/10.1007/s13201-017-0579-4, 2017
[21] A.R Dirisu., J.O. Olomukoro. Investigation of water quality of two rivers in Agbede – Wetlands in Southern Nigeria. Global NEST Journal, 17(3): 451-462. https://doi.org/10.30955/gnj.001420, 2015.
[22] Ahmad I. Khwakaram, Salih N. Majid, Nzar Y. Hama. Determination of water quality index (WQI) for Qalyasan Stream In Sulaimani City/Kurdistan Region Of Iraq. International Journal of Plant, Animal and Environmental Sciences, 2 (4): 148-157, 2012.
[23] Abdul Hameed M. JawadAlobaidy, et al. Application of water quality index for assessment of Dokan Lake ecosystem, Kurdistan region, Iraq.Journal of Water Resource and Protection, 2010, 2, 792-798, https://doi.org/10.4236/jwarp.2010.29093, 2010.
[24] Ramakrishnaiah CR, Sadashivaiah C, Ranganna G. Assessment of water quality index for the Groundwater in TumkurTaluk, Karnataka State India. J Chem 6:523–530.https://doi.org/10.1155/2009/757424, 2009.
[25] Curtis G. Cude. Oregon water quality index a tool for evaluating water quality management effectiveness. The Journal of the American Water Resources Association, Paper No. 99051. https://doi.org/10.1111/j.1752-1688.2001.tb05480.x, 2007.
[26] Yadav A K, Khan P, Sharma SK. Water quality index assessment of groundwater in Todaraisingh Tehsil of Rajasthan State, India—a greener approach. J Chem 7:S428–S432. https://doi.org/10.1155/2010/419432, 2010.
[27] Yuvraj Singh, Manish Kumar Jain "Assessment of water quality index: A case study of the Jalmahal lake area, Jaipur-Rajasthan" Journal of Ecology, Environment and Conservation, 24: 80-85,ISSN: 0971-765X, 2018.
[28] F.J. Thakor, D.K. Bhoi, et al. Water quality index (WQI) of Pariyej Lake dist. Kheda – Gujarat, Current World Environment, Vol. 6(2): 225-231, 2011
[29] S. K. Singh, Deepika. Water quality index assessment of Bhalswa Lake, New Delhi, International Journal of Advanced Research 3(5):1052-1059, 2015.
[30] United State Environmental Protection Agency (US-EPA). Port Gamble S'Klallam tribe water quality standards for surface waters. A technical report: 1-37, 2002..
[31] ACT Water Quality Report 2000–2001, Environment Act, pp. 13-36, 2001.
[32] Shimadzu Excellence in Science.Application Handbook on Sum Parameter (Release 4). Shimadzu Europa GmbH, SEG-A-099: 1-142, 2018.
[33] Liu, Xuemei, Guangxin Zhang, *et al.* Assessment of Lake Water Quality and Eutrophication Risk in an Agricultural Irrigation Area: A Case Study of the Chagan Lake in Northeast China" Water 11, no. 11: 2380. https://doi.org/10.3390/w11112380, 2019.
[34] Ashritha R Murthy, K M Anil Kumar. A Review of Different Approaches for Detecting Emotion from Text. IOP Conf. Ser.: Mater. Sci. Eng. 1110 012009, https://doi.org/10.1088/1757-899X/1110/1/012009, 2021.

[35] Rodgers; Nicewander. "Thirteen ways to look at the correlation coefficient" (PDF). The American Statistician. 42 (1): 59–66. https://doi.org/10.2307/2685263.JSTOR, 1988.
[36] HaldunAkoglu. User's guide to correlation coefficients. Turkish Journal of Emergency Medicine, Volume 18, Issue 3, Pages 91-93, https://doi.org/10.1016/j.tjem.2018.08.001, 2018.
[37] Richard Taylor, EDD, RDCS. Interpretation of the Correlation Coefficient: A Basic Review. JDMS January/February 1990.