Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 22 October 2021 doi:10.20944/preprints202110.0325.v1

Calculation of quality indices and correlation factors at some effluents entry points of the 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: With this article, impact of effluent mixed water with the quality of the Mansagar Lake has been established by evaluating the physico-chemical parameters and the heavy-metal contents experimentally. The process of calculating water quality and the metal pollution quality indices is also explained in brief with respect to selected sample locations and varied environmental conditions (Pre- and Post-Monsoon season). Distribution trends of Pearson's correlation factor have also been discussed to establish their relation among the physico-chemical parameters and the heavy-metal contents for varied environmental conditions. In the end, detailed discussion on observations made during this study and useful recommendations are also elaborated in details. With this article, we intend to present a document for better understanding of the water quality of this lake in view of futuristic management strategies to be adopted to maintain it heritage values.

Keywords: Pollution in Lakes, Quality assessment, Water and metal quality index, Metal pollution index, Correlation analysis.

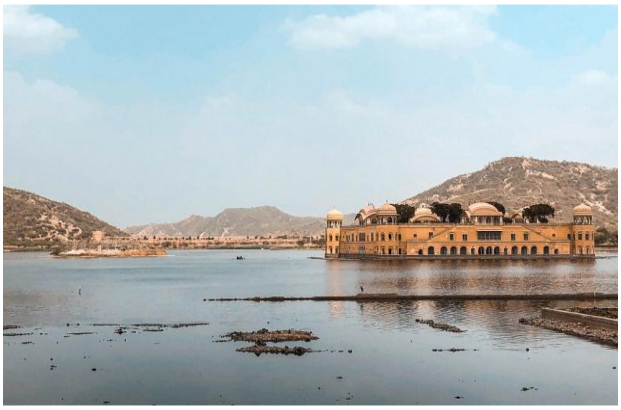
INTRODUCTION:

Effluent or waste water is the output of the septic tank or sewage treatment plant which treats the sewage water. It is also referred "trade effluent" mainly contributed by commercial activities [1-3]. Jaipur city is famous for its heritage, ancient structures and cultural activities and beautiful lake; Mansagar lake, which situated in the north part of the city. The lake also hosts a heritage structure popularly known as; the Jalmahal place in the middle, which attracts lots of tourists throughout the year. However lack of proper maintenance and unusual behavior of the visitors have been a major concern to maintain the water quality of the lake, which is deteriorating each year due to pollution burden by the point and non-point sources [4-6]. The water quality index (WQI) has been used to establish associationship among the physico-chemical parameters with the quality of the surface and ground water of urban lakes [7-9]. Similarly, metal quality and pollution index (MQI, MPI) are effective parameters to develop management strategies to control surface water metallic pollution [10-15]. This article is our extended work in addition to previously published work [4], whereby dominant evaluated physico-chemical parameters and the metal contents have been used to calculate the WQI, MQI and MPI to establish their trends with varied sample locations and varied environmental conditions. Distribution analysis for evaluated quality parameters; WQI, MQI and MPI have been also done to check their variation with respect to the variation in the environmental conditions (pre- and post-monsoon sampling days). The Pearson's correlation analysis has been used to determine the associationship among the physico-chemical parameters. Similar calculations are also done to correlate the metal constituents and to check impact on each other for varied environmental conditions. In the last detailed discussion on the outcomes and possible remedies to maintain the heritage value of the studied lake is presented followed by conclusion and a list of references.

GENERAL CONCEPTS ABOUT POLLUTANTS IN URBAN LAKES AND THE STUDIED LAKE:

The survival and multiplication of microorganisms in urban lakes is influenced by various factors of which nutrients and Oxygen are the most important one. Perhaps, presence of ammonia in excess also generates pollution threats for lakes and ponds. The temperature, pH, light suspended matter, total dissolved solids (TDS), toxic inorganic and organic compounds are other important factors influencing growth of microorganisms. The types of organic compound available as well as nitrogen and phosphorus play important role in the biomass formation and depletion of oxygen. Other water contaminants also accumulate in the soil over the period of time and turn the soil unfit for agriculture. Most of the water bodies in the city of Jaipur and nearby regions have been facing problems of ever-increasing levels of the nitrate and phosphate from other sources. The studied lake; Mansagar Lake with a palace in the middle is situated in the north part of the Jaipur City was built in the year 1610 [7].

As shown in the figure 1(a), the lake is surrounded by hills from three sides. It can be defined by its depth (1.5-4.5 in meters), surface area (139 hectares) and the catchment area, which is 23.5 sq. km [4-5]. The state Government and local municipal agencies have been working hard to manage its heritage value and to maintain the quality of its water since last 2 decades. Even then, excess tourism activities, uncontrolled waste mixing and untreated sewage from nearby residents and local industries have been challenging issues since long. Continuous variation in physico-chemical parameters and constituent metal pollutants water make its uses difficult for domestic purposes and posing serious health hazard to living beings. Its water quality deteriorate more often due to nearby effluents especially in rainy days, whereby the pollutants and hazardous metallic contents mixed with it via rainy water from adjoining rough areas and the roads. Also rain on nearby hills has been a primary cause for the soil erosion and to transfer the silt deposit in the lake thereby reduces its coverage area and affect the water quality severely [7]. This is a continuous phenomena going with the studied lake since long.



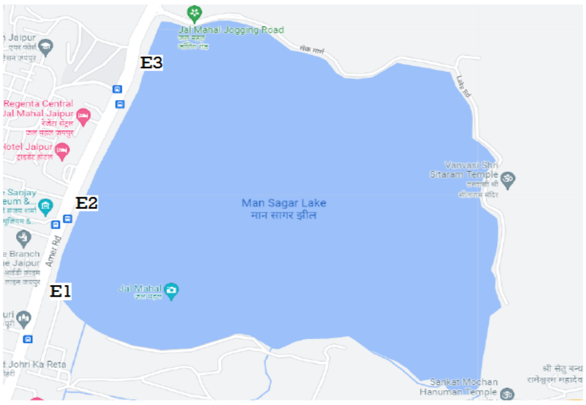


Fig. 1 (a) Road side view of Mansagar Lake, courtesy: https://www.backpackingwithmylens.com/2019 (b) the sample stations (E_1, E_2, E_3), courtesy https://www.google.co.in/maps/@26.9555716,75.8464121,16.02z.

With a purpose to assess the quality of effluent water entering into the lake, we decided to select 03 strategic locations to collect the samples next year (with varied seasonal conditions: Pre- and Post-Monsoon). We selected three sample stations; E_1-front of local weekly market (Haat Bazar), E_2-Sanjay Museum and E_3- end point of the Gujar Ghati. These locations were chosen on the basis possible anthropogenic activities, tourist movements and waste contribution from nearby commercial premises. The exact locations may be checked from the satellite image as depicted in the figure 1 (b). The location (station: E_3) was also suitable in view to check the soil erosion effects and its impact on the lake environment. As discussed in [4-7], standard processes and methodologies were applied to evaluate the physico-chemical parameters and metal constituents for samples collected from stations; E_1, E_2, and E_3. Table 1 depicts evaluated physico-chemical parameters, organic effluents and other pollution contents for these chosen locations. The table is reproduced from earlier reported work [4] with some parameters close to their two decimal values only. Large variations were observed within the physico-chemical, biological and bacteriological parameters, which also indicate that the Jalmahal (Mansagar) lake prevailing a non-uniform nature of the water quality. Tabulated parameters also confirm presence of contaminations at all sample locations due to higher chemical Oxygen demand (COD) levels, while dissolved Oxygen (DO) levels remains at lower side at E_1 station. We also observed slight variation in the pH values in a range 6.70 to 7.58, which is suitable range for fishes to grow in the water. The observed variation in pH can be due to atmosphere, biological activities and temperature changes.

Similarly, the observed DO levels can be used to determine that the changes in the biological properties of water and it should be 4mg/l for aquatic water. The dissolved oxygen of water is introduced through air or photosynthesis. The oxygen contains reduced due to organic matter, rise in temperature and due to inorganic compounds like H_2S, NH_3, NO_3 and ferrous Iron. In most observed samples, the DO value is found low, which may impacting the WQI of the aquatic water. Other physico-chemical parameters, which were evaluated from the collected samples, were conductivity, total organic carbon (TOC), Ammonical Nitrogen, Nitrate (NO_3) and Phosphate (PO_4). Chloride is the most common inorganic compound and is found in practically in all natural sources of water. Man and animals excrete high quantity of Chloride. Also, the higher values of the Biological Oxygen demand (BOD) at stations at the edges impacting the WQI values, while the turbidity is not found as the impactful factor on calculation of WQI as compared to the measured values of TDS. The discharging of impurities from anthropogenic activities and run off from rain water and closing of tertiary treatment plant is the main factor for contamination.

Table 1: Evaluated Physico-chemical parameters for sample collected from; E_1, E_2 and E_3; Reproduced from Ref. [4]

Sample Location	Haat Bazar front (E1)		Sanjay Museum (E2)		Gujar Ghati End (E3)	
Parameters (standard unit) /Season	*Pre-Monsoon*	*Post-Monsoon*	*Pre-Monsoon*	*Post-Monsoon*	*Pre-Monsoon*	*Post-Monsoon*
pH (pH unit)	7.58	6.92	7.42	6.85	7.22	6.70
Conductivity (µS/cm)	1007	950	1800	1615	1350	1180
Turbidity (NTU)	4.22	6.95	7.42	8.44	12.2	14.4
Total organic carbon	390.4	405.5	339.5	355.8	416	425.2
Total Kjeldahl Nitrogen	38.20	31.30	34.20	29.40	36.40	29.40
Dissolved Oxygen	1.6	2.8	3.6	4.9	4.5	4.8
Chloride	139.95	129.95	154.95	142.2	179.94	157.95
Ammonical Nitrogen	1.20	1.42	1.15	1.70	0.57	0.85
Coliform Bacteria	22.0	23.0	22.0	21.0	23.0	23.0
Biological Oxygen demand	22	17.64	25.30	24.83	24.40	22.83
Chemical Oxygen demand	776	460.5	180.4	270.4	315.4	336
NO_3	0.20	0.28	0.18	0.22	0.25	1.27
PO_4	3.40	7.10	3.70	4.60	4.30	5.08

As compared to our previously reported work [4], we extended the work by evaluating additional performance parameters such as Phosphate, Nitrate and Total Kjeldahl Nitrogen (TKN) contents to define quality characteristics parameters. Usually typical range is 35 to 60 mg/L for TKN in urban water bodies, which defines organic nitrogen and ammonia presence with their surface water. For our study with the Mansagar Lake, the TKN values found in the prescribed range only, with a little increasing pattern during post-monsoon sampling time. The chloride contents found more in pre-monsoon days, which may react with Mn to form $MnCl_2$ and other dangerous mixtures, which may becan be detrimental. The coliform bacteria (E. coli) are present in all water bodies and its higher concentration indicates more contaminated water quality. Its high value is not suitable aquatic species and thereby increases the possibility of disease spreading among them. This may enter into the lakes through waste produced by the municipal, farm, animal and human and other outdoor activities. With our study, we also observed that most of the nonpoint sources create significant effects on bacterial level in the water.

We also noticed presence of micro-organisms, indicating coliform bacteria existence within the lake water. In our study, we recoded the fecal coliform density as the number of organisms less than 23 per 100 ml. It is clear, that traced presence of Coliform bacteria are not creating life threatening situations, however its presence may be an indication of pathogens, which may cause water borne diseases. We also noticed that the Ammoniacal nitrogen quantity is in permissible limit for outlets of nearby sewage treatment plant, however harmful for fishes. On the contradictory, levels of the Phosphate and TKN were found relatively high. The maximum level of phosphorous needs to be at 0.03 mg/l, naturally in water phosphate lies in the range of 0.005 to 0.05 mg/l. We also noticed increase in the levels of phosphorus and nitrogen increases during post-monsoon days/months.

Table 2: Levels of metal constituents evaluated from samples collected from chosen locations; Reproduced from Ref. [4]

Station	E_1		E_2		E_3	
Metal (mg/L)	*Pre-Monsoon*	*Post-Monsoon*	*Pre-Monsoon*	*Post-Monsoon*	*Pre-Monsoon*	*Post-Monsoon*
Cr	0.30	0.35	0.25	0.30	0.24	0.28
Co	0.01	0.01	0.02	0.01	0.02	0.01
Cd	0.01	0.02	0.01	0.01	0.01	0.02
Cu	0.03	0.04	0.04	0.04	0.03	0.05
Na	141.0	129	251.6	175.0	173.0	121.0
K	14.2	10.6	60.5	29.8	38.6	24.5
Ca	315.4	155.0	231.0	135.0	207.45	129.8
Fe	0.20	0.09	0.81	0.06	0.37	0.29
Mn	0.05	0.04	0.08	0.07	0.07	0.07
Ni	0.03	0.02	0.05	0.04	0.08	0.06
Pb	0.02	0.03	0.01	0.02	0.02	0.04
Zn	0.92	0.45	0.68	0.14	0.82	0.35

Presence of chromium (Cr) within the lake water can affect special part of the aquatic animals such as like fish gills. Its levels should not be greater than 0.1 mg/l in the drinking water. Higher levels of Cr may affect aquatic plants too in urban water bodies. The dissolved salts of calcium and magnesium can create hardness in the water. Similarly, presence of other metal impurities such as the Cobalt (Co) and Cadmium (Cd) in the drinking water must not cross the level of 0.05 mg/l and 0.005 mg/l respectively as per US environmental protection agencies. Considering these facts, we extended our study to evaluate more types of metal constituents available with the studied lake water. The table 2 depicts the evaluated values of the heavy metal pollutants at chosen sampling stations. The table is reproduced here from earlier reported work [4] with some parameters close to their two decimal values. As compared to table given in earlier work [4], we have completed additional experimental work to evaluate the values of remaining parameters. With rigorous assessment of samples collected from chosen locations, we observed that levels of some evaluated metal constituents (Cr, Mn, Na, K, etc.), were relatively at higher side, causing water quality deterioration. Perhaps in the year of 2017, higher levels of Cr, Mn and Na resulted in aquatic living beings in huge numbers, which attracted many environmentalists to study causes to alarm the bell. On the other hand, higher levels of Na also have impact on lake bed soil quality. With the experimental exercises, we noticed variation in the range from 121 mg/L - 252 mg/L and in the range 10 mg/L - 60 mg/L for evaluated Na and K respectively, which may be due to runoff from the sewage lines, washing activities and flooded rain water in the lake. We observe higher concentration levels of Na & K, which eventually affecting the aquatic animals and plants severely. The levels of other evaluated metal constituents can be referred from table 2.

BASIC THEORY OF WATER, METAL QUALITY AND POLLUTION INDEX (WQI, MQI & MPI):

We have analysed the overall water quality using important parameters; temperature, Nitrate, Phosphate, DO, pH, TOC, turbidity, etc. by associating the water quality (Q) and weighing factor (w). Detailed weighted arithmetic index method to calculate the WQI can be referred from our previous work [7] and theories mentioned with [8-9]. With this work, we also focused on demonstrating the WQI values describing the spatial and temporal water quality information. The metal pollution index (MPI) is calculated to determine the quality of the water and its suitability for aquatic purposes [16-18].

Table 3: Permissible limits of heavy metals in the water (mg/l), ref. [19-22]

Metal	Standard Value	Reference
Cr	0.05	WHO (2003), BIS (2009), India CPCB (BIS 10500: 2012)
Pb	0.05	WHO (2006), BIS (2009), India CPCB (BIS 10500: 2012)
Zn	5-15	WHO (2003), BIS (2009), India CPCB (BIS 10500: 2012)
Cd	0.003	WHO (2003), BIS (2009), India CPCB (BIS 10500: 2012)
Cu	0.05	BIS (2009), India CPCB (BIS 10500: 2012)
Na	60	BIS (2009), India CPCB (BIS 10500: 2012)
K	10	BIS (2009), India CPCB (BIS 10500: 2012)
Ca	200	India CPCB (BIS 10500: 2012)
Fe	0.3	WHO, India CPCB (BIS 10500: 2012)
Mn	0.1-0.3	India CPCB (BIS 10500: 2012)
Ni	0.02	BIS (2009), India CPCB (BIS 10500: 2012)

We have calculated the MPI as per the standard model in use [11-12], while taking in consideration various inorganic and metal constituents such as Iron, manganese, lead, copper, nickel, cadmium, chromium, zinc, etc. These performance (WQI and MPI) facts may also be utilized to narrate requisite concrete planning for restoration of the lake. The standard values for common heavy metal constituents in lake water are listed in the table 3. This table is prepared with the report released by WHO and BIS in past [14-15], [19-22]. The values for some parameters may vary in accordance to the intended use of the water such as for drinking and irrigation purposes, aquatic life and as per the level of the water: surface or ground water [23-26]. The metal pollution index has been calculated by;

$$Q_i = \Sigma [(M_i - M_{id}) / (M_s - M_{id})] \times 100 \text{ ----------- [1]}$$

$$MPI = \Sigma\, Q_i W_i / \Sigma W_i \text{ ----------- [2]}$$

Where M_i, M_s and M_{id} are monitored, standard and ideal values of i^{th} parameter respectively. A comparision between the evaluated metal concentrations with their maximum permissible limit (M_s) defines the quality [23-26]. Metal quality index (MQI) value >1 is a threshold of warning [13]. According to [14-15], the MQI is calculated by;

$$MQI = \Sigma M_i/M_s \text{ ----------- [3]}$$

3.1 DETERMINITATION OF WATER QUALITY INDEX:

As described in previous paragraph, the calculation of WQI using the evaluated physico-chemical parameters has been completed. The lake water has been subjected for analysis of various physiochemical parameters such as pH, turbidity, DO, BOD, Nitrate, Phosphate etc. Tables from 4 to 5 depicts the data obtained and subsequent calculated WQI values for samples collected for varied environmental conditions and from the chosen stations. On the basis of calculated WQI values, it can be predicted that the lake water quality is slightly pollute in nature although still in the acceptable range for aquatic animals like fishes. The calculated WQI values may be use to plan strategies for maintenance and installing new effluents entry points. We have further analyzed the values obtained for WQI levels for their actual and mean values station-wise for varied environmental conditions. These values are used to obtain the BAR charts as depicted by the figure 2. 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.

Table 4: Calculated WQI values for samples collected during Pre-Monsoon season

Locations:			*Station-E_1*			*Station-E_2*			*Station-E_3*		
Parameter	V_s	W_i	V_o	Q_i	W_iQ_i	V_o	Q_i	W_iQ_i	V_o	Q_i	W_iQ_i
pH	8.5	0.2190	7.58	38.67	8.47	7.42	28.00	6.13	7.22	14.66	3.21
BOD	5.0	0.3723	22	440	163.81	25.30	506.00	188.38	24.40	488	181.68
DO	5.0	0.3723	1.60	135.41	50.41	3.60	114.58	42.66	4.50	105.21	39.17
Turbidity	5.0	0.3723	4.22	84.4	31.42	7.42	148.4	55.25	12.2	244	90.84
CL	1000	0.0019	139.95	13.99	0.03	154.95	15.49	0.03	179.94	17.99	0.03
TOC	300	0.0062	390.4	130.13	0.80	339.5	113.17	0.70	416	138.67	0.86
Nitrate	45	0.0414	0.20	0.44	0.02	0.18	0.40	0.02	0.25	0.55	0.02
Phosphate	24	0.0775	3.40	14.16	1.09	3.70	15.42	1.19	4.30	17.92	1.39
	$\Sigma W_i = 1.4629$		$\Sigma Q_iW_i = 256.05$			$\Sigma Q_iW_i = 294.36$			$\Sigma Q_iW_i = 317.20$		
Water quality index (WQI)			$(WQI)E_1 = 175.02$			$(WQI)E_2 = 201.21$			$(WQI)E_3 = 216.83$		

Table 5: Calculated WQI values for samples collected during Post-Monsoon season

Locations:			*Station-E_1*			*Station-E_2*			*Station-E_3*		
Parameter	V_s	W_i	V_o	Q_i	W_iQ_i	V_o	Q_i	W_iQ_i	V_o	Q_i	W_iQ_i
pH	8.5	0.2190	6.92	5.33	1.17	6.85	10.00	2.19	6.70	20.00	4.38
BOD	5.0	0.3723	17.64	352.80	131.35	24.83	496.60	184.88	22.83	456.60	169.99
DO	5.0	0.3723	2.80	122.91	45.76	4.90	101.04	37.62	4.80	102.08	38.00
Turbidity	5.0	0.3723	6.95	139	51.74	8.44	168.8	62.84	14.4	288	107.22
CL	1000	0.0019	129.95	12.99	0.02	142.20	14.22	0.03	157.95	15.79	0.03
TOC	300	0.0062	405.5	135.17	0.84	355.8	118.60	0.74	425.2	141.73	0.88
Nitrate	45	0.0414	0.28	0.62	0.03	0.22	0.48	0.02	1.27	2.82	0.11
Phosphate	24	0.0775	7.10	29.58	2.29	4.60	19.17	1.49	5.08	21.17	1.64
	$\Sigma W_i = 1.4629$		$\Sigma Q_iW_i = 233.20$			$\Sigma Q_iW_i = 289.81$			$\Sigma Q_iW_i = 322.25$		
Water quality index (WQI)			$(WQI)E_1 = 159.41$			$(WQI)E_2 = 198.10$			$(WQI)E_3 = 220.28$		

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 22 October 2021 doi:10.20944/preprints202110.0325.v1

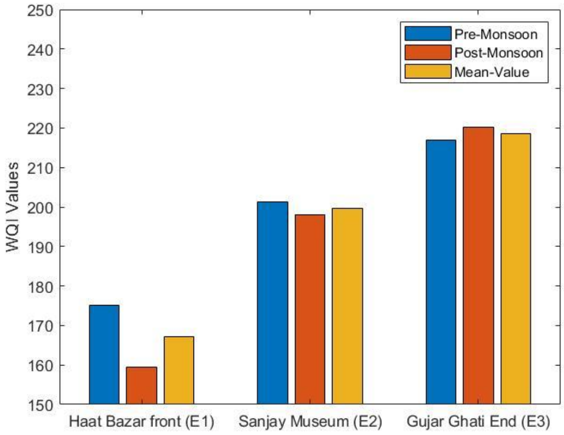


Fig. 2: Graphical representation (bar charts) distribution of water Quality Index (WQI) values season wise

3.2 METAL QUALITY & POLLUTION INDEX CALCULATIONS:

During the study and analytical work related to evaluation of the MQI and MPI values for measured data, we found that the water of the studied lake (Mansagar) is contaminated by various metals, thereby is actually not suitable for domestic uses. Thus, it is recommended to manage the sewage treatment with utmost priority to have control on the effluents and their entry within the lake. As described in previous paragraph and the standards values mentioned in the table 3, the calculation of MQI and MPI have been done. Tables 6 to 7 depicts the data obtained and subsequent calculated MQI and MPI values for samples collected during pre- and post monsoon days for chosen locations; E_1, E_2 and E_3. We have further analyzed the values obtained for MQI and MPI levels for their actual and mean values station-wise for varied environmental conditions. These values are used to obtain the BAR charts as depicted by the figure 3. Henceforth the values shown by the MQI and MPI data tables can also be useful interpretation of quality issues and to initiate actions with appropriate methodologies for maintaining the water quality of the lake.

Table 6: Calculated MQI and MPI values for samples collected during Pre-Monsoon season.

Locations:			*Station-E_1*			*Station-E_2*			*Station-E_3*		
Metal	M_s	W_i	M_i	Q_i	W_iQ_i	M_i	Q_i	W_iQ_i	M_i	Q_i	W_iQ_i
Cr	0.05	20	0.30	600	12000	0.25	500	10000	0.24	480	9600
Co	0.05	20	0.01	20	400	0.02	40	800	0.02	40	800
Cd	0.03	33.34	0.01	34	1133.56	0.01	34	1133.56	0.01	34	1133.56
Cu	0.05	20	0.03	60	1200	0.04	80	1600	0.03	60	1200
Na	60	0.02	141.0	235	3.99	251.6	419	7.12	173.0	288	4.90
K	10	0.10	14.2	142	14.2	60.5	605	60.5	38.6	386	38.6
Ca	200	0.01	315.4	158	0.79	231.0	115	0.57	207.45	103.7	0.52
Fe	0.3	3.34	0.20	67	223.78	0.81	270	901.8	0.37	123	410.82
Mn	0.3	3.34	0.05	17	56.78	0.08	27	90.18	0.07	23.3	77.82
Ni	0.02	50.0	0.03	150	7500	0.05	250	12500	0.08	400	20000
Pb	0.05	20.0	0.02	40	800	0.01	20	1.0	0.02	40	800
Zn	15	0.07	0.92	6.13	0.41	0.68	4.5	0.30	0.82	5.4	0.36
ΣW_i= 170.20			$(MQI)E_1 = 15.30$			$(MQI)E_2 = 23.64$			$(MQI)E_3 = 19.83$		
			ΣQ_iW_i= 23333.51			ΣQ_iW_i= 27095.03			ΣQ_iW_i= 34066.58		
Calculated MPI			$(MPI)E_1 = 139.09$			$(MPI)E_2 = 159.19$			$(MPI)E_3 = 200.15$		

Table 7: Calculated MQI and MPI values for samples collected during Post-Monsoon season.

Locations:			*Station-E_1*			*Station-E_2*			*Station-E_3*		
Metal	M_s	W_i	M_i	Q_i	W_iQ_i	M_i	Q_i	W_iQ_i	M_i	Q_i	W_iQ_i
Cr	0.05	20	0.35	700	14000	0.30	600	12000	0.28	560	11200
Co	0.05	20	0.01	20	400	0.01	20	400	0.01	20	400
Cd	0.03	33.34	0.02	67	2233.78	0.01	34	1133.56	0.02	67	2233.78
Cu	0.05	20	0.04	80	1600	0.04	80	1600	0.05	100	2000
Na	60	0.017	129	215	3.65	175.0	292	4.96	121.0	202	3.43
K	10	0.10	10.6	106	10.6	29.8	298	29.8	24.5	245	24.5
Ca	200	0.005	155.0	77	0.38	135.0	67	0.33	129.8	65	0.32
Fe	0.3	3.34	0.09	30	100.2	0.06	20	66.8	0.29	97	323.98
Mn	0.3	3.34	0.04	13	43.42	0.07	23	76.82	0.07	23	76.82
Ni	0.02	50.0	0.02	100	5000	0.04	200	10000	0.06	300	15000
Pb	0.05	20.0	0.03	60	1200	0.02	40	800	0.04	80	1600
Zn	15	0.067	0.45	3	0.20	0.14	1	0.07	0.35	2	0.13
ΣW_i= 170.20			$(MQI)E_1$ = 14.71			$(MQI)E_2$ = 16.75			$(MQI)E_3$ = 17.61		
			ΣQ_iW_i= 24592.23			ΣQ_iW_i= 26112.34			ΣQ_iW_i= 30862.96		
Calculated MPI			$(MPI)E_1$ = 144.49			$(MPI)E_2$ = 153.42			$(MPI)E_3$ = 181.33		

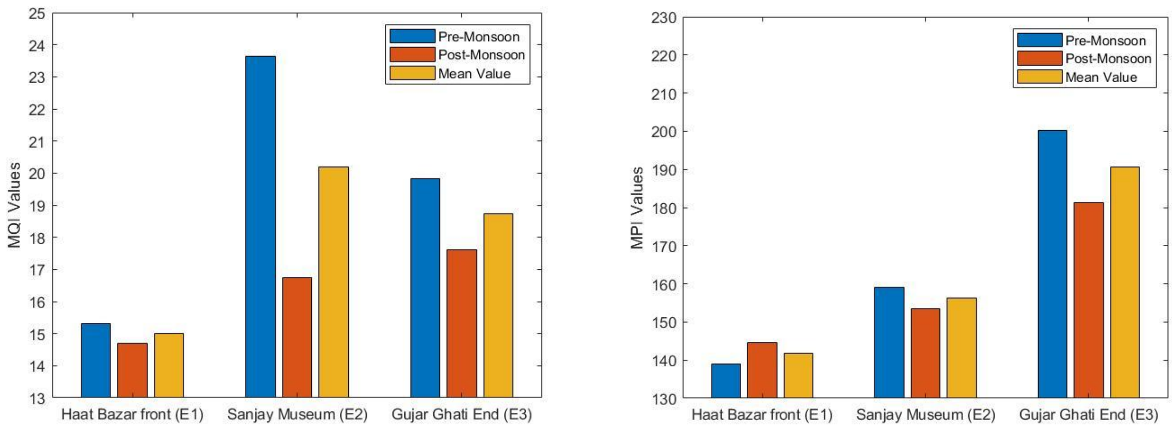


Fig. 3: Graphical representation (bar charts) distribution of MQI and MPI values season wise

PEARSON CORRELATION ANALYSIS:

Bivariate analytical methods have been in use to correlate the physico-chemical parameters and to metal constituents for a lake. Such analyses are useful to check the associationship among the lake characteristics parameters by defining the correlation coefficient ranges between +1 and -1. This coefficient is determined usually by any of the four correlation methods such as; the Pearson, Linear, Sample and the Population correlation method. In next part of the evaluation process, we calculated the Pearson's correlation coefficient ('*r*') for measured physico-chemical and other important parameters evaluated for samples collected from the effluent entry locations (E_1-E_3). Details of the Pearson' correlation analytical method can be referred from our previous reported article [7]. Tables 5 and 6 depicts the correlation table (Pearson's method) for these stations for post- and pre monsoon seasons respectively. The correlation coefficient '*r*' is calculated up to two decimal values only for easy interpretation of the associationship. In addition to the previously used abbreviated parameters [7]; the matrices are also indicating correlation for Ammonical Nitrogen (NH_3-N), Coliform Bacteria (E-coli), Nitrate (NO_3) and the Phosphate (PO_4). From table 5, it is clear that the evaluated Pearson correlation coefficient '*r*' for post-monsoon days, indicate very strong positive association between pH with NH_3-N (0.79) and TKN (0.74), BOD and conductivity (0.91), turbidity with Chloride (0.97) and DO (0.79), TOC with NO_3 (0.75) and PO_4 with

COD (0.98) and with TKN (0.98), etc. While parameters such as conductivity and NH_3-N, DO with NO_3, TOC with PO_4, etc. are strong positively associated with each other. On the other hand, the association of the pH with turbidity and chloride, conductivity with COD and E-coli and COD with BOD and DO is very strongly negative; almost inversely proportional to each other.

Table 5: Correlation table for evaluated physico-chemical parameters; Post-Monsoon season

	pH	Conductivity	Turbidity	COD	DO	BOD	TOC	Chloride	NH_3-N	E. coli	TKN	NO_3	PO_4
pH	1												
Conductivity	-0.14	1											
Turbidity	-0.99	0.01	1										
COD	0.47	-0.94	-0.36	1									
DO	-0.72	0.79	0.62	-0.95	1								
BOD	-0.54	0.91	0.43	-0.99	0.97	1							
TOC	-0.47	-0.81	0.57	0.55	-0.28	-0.49	1						
Chloride	-0.99	0.27	0.97	-0.59	0.80	0.65	0.34	1					
NH_3-N	0.79	0.48	-0.87	-0.15	-0.15	0.08	-0.90	-0.71	1				
E. coli	-0.21	-0.94	0.33	0.76	-0.54	-0.71	0.96	0.07	-0.75	1			
TKN	0.74	-0.77	-0.65	0.94	-0.99	-0.96	0.24	-0.82	0.19	0.5	1		
NO_3	-0.93	-0.23	0.97	-0.13	0.42	0.19	0.75	0.87	-0.96	0.54	-0.46	1	
PO_4	0.61	-0.87	-0.51	0.98	-0.99	-0.99	0.41	-0.71	0.01	0.64	0.98	-0.29	1

Table 6: Correlation table for evaluated physico-chemical parameters; Pre-Monsoon season

	pH	Conductivity	Turbidity	COD	DO	BOD	TOC	Chloride	NH_3-N	E. coli	TKN	NO_3	PO_4
pH	1												
Conductivity	-0.37	1											
Turbidity	-0.99	0.32	1										
COD	0.69	-0.92	-0.65	1									
DO	-0.96	0.61	0.94	-0.86	1								
BOD	-0.65	0.94	0.61	-0.99	0.83	1							
TOC	-0.39	-0.71	0.43	0.39	0.11	-0.44	1						
Chloride	-0.99	0.29	0.99	-0.63	0.93	0.59	0.46	1					
NH_3-N	0.93	0.00	-0.94	0.36	-0.78	-0.32	-0.70	-0.95	1				
E. coli	-0.89	-0.07	0.91	-0.30	0.73	0.25	0.75	0.92	-0.99	1			
TKN	0.39	-0.99	-0.34	0.93	-0.63	-0.95	0.69	-0.31	0.01	0.05	1		
NO_3	-0.73	-0.35	0.77	-0.02	0.52	-0.02	0.90	0.78	-0.93	0.96	0.33	1	
PO_4	-0.99	0.25	0.99	-0.59	0.91	0.55	0.50	0.99	-0.96	0.94	-0.27	-0.27	1

Similarly, we can identify the relationship between other parameters as per the value of '*r*' as defined in [7]. This interpretation of associationship among evaluated parameters from collected samples during pre-monsoon season can be defined for data given in the table 6. We have noticed important observations by comparing and correlating the values of '*r*' from table 5 and 6, which are listed below;

- The associationship between the pH with turbidity and chloride remain same (very strong negative) irrespective of changes in the environmental conditions.
- The association of COD with parameters such as BOD, DO and Chloride remains negative in nature (very strong to strong).
- The association of Ammonical Nitrogen (NH_3-N) with E. coli and NO_3 remains negative in nature (very strong to strong).

- The relation of TOC with E. coli, NO_3 and PO_4 remains positive (strong to very strong positive associationship).

In urban areas with random environmental conditions, heavy metals constituents of water bodies can interact with each other and may subsequently transformed in different phases [27-28]. Such phase transform can alter biogeochemical behaviors of the metal's constituents of a water body due to their changed response to environmental variations [29]. During our study for metal constituents in the Mansagar Lake, low levels of metal concentrations irrespective of environmental variations establish nominal impact of the environmental conditions on them. We observe that the distribution pattern of most of metals indicates a little seasonal variation. Although the associationship among metals were different for different seasonal days. To estimate the associationship, we calculated the Pearson's correlation coefficient ('*r*') up to two decimals only for measured metal constituents for samples collected from the effluent entry locations (E_1-E_3). Tables 7 and 8 depicts the correlation table (Pearson's method) for these stations for post- and pre monsoon seasons respectively. From table 7, we can observe that the evaluated Pearson correlation coefficient '*r*' for post-monsoon days, indicate very strong positive association between Cu with Fe (0.99), and Ni and Pb (both +0.87) and K with Mn and Ni (+0.96 and +0.70 respectively), and Fe with Ni and Pb (+0.79 and +0.92 respectively). While metal pairs such as Cr and Zn, Cu and Mn, Ca and Zn, Ni with Zn and Pb possesses strongly positive association.

Table 7: Correlation table for evaluated heavy-metal constituents; Post-Monsoon season

	Cr	Cu	Na	K	Ca	Fe	Mn	Ni	Pb	Zn
Cr	1									
Cu	-0.72	1								
Na	-0.10	-0.61	1							
K	-0.85	0.25	0.61	1						
Ca	0.99	-0.66	-0.19	-0.89	1					
Fe	-0.63	0.99	-0.70	0.13	-0.56	1				
Mn	-0.96	0.50	0.38	0.96	-0.98	0.39	1			
Ni	-0.97	0.87	-0.14	0.70	-0.94	0.79	0.87	1		
Pb	-0.28	0.87	-0.93	-0.26	-0.19	0.92	0.01	0.50	1	
Zn	0.53	0.20	-0.89	-0.89	0.60	0.31	-0.75	-0.32	0.66	1

Table 8: Correlation table for evaluated heavy-metal constituents; Pre-Monsoon season

	Cr	Cu	Na	K	Ca	Fe	Mn	Ni	Pb	Zn
Cr	1									
Cu	-0.36	1								
Na	-0.61	0.96	1							
K	-0.79	0.85	0.96	1						
Ca	0.99	-0.31	-0.56	-0.76	1					
Fe	-0.59	0.96	0.99	0.96	-0.55	1				
Mn	-0.88	0.76	0.91	0.98	-0.86	0.90	1			
Ni	-0.88	-0.11	0.17	0.43	-0.90	0.16	0.56	1		
Pb	0.36	-1.0	-0.96	-0.85	0.30	-0.96	-0.76	0.11	1	
Zn	0.71	-0.90	-0.99	-0.99	0.68	-0.99	-0.96	-0.31	0.91	1

On the other hand, the association of the Cr with Cu, K, Mn, and Ni is very strongly negative; almost inversely proportional to each other. To best of our knowledge, first time a detailed study has been done for the correlation analysis of metal pollutants (i.e., Cr, Cu, Na, K, Ca, Fe, Mn, Ni, Pb and Zn) for varied environmental conditions for the Mansagar lake water quality. This interpretation of associationship among evaluated parameters from collected samples during pre-monsoon season can also be defined for data given in the table 8. We may also notice interesting observations by comparing and correlating the values of '*r*' from table 7 and 8, some of which are listed below;

- The associationship of the Cr with Cu remain same (very strong positive), while with Mn and Ni, the associationship is very strong negative irrespective of changes in the environmental conditions.
- The association of Cu with Fe is very strong positive and with Mn always above string positive in both seasons.
- The associationship of K with Ca and Zn remains very strong negative irrespective of seasonal variations. Similarly, the relationship of Ca with Mn and Ni remains very strong negative in all whether situations.

CONCLUSION:

With this article, we have discussed calculation of quality indices (water quality index, metal quality index) and Pearson's correlation factors. A detailed description for calculation of quality indices and correlations among the physicochemical parameters and constituent metal contents has also been presented. The evaluated quality indices may help to define guidelines to manage and maintain the lake and surrounding environment. On the other hand, evaluated correlation factors can be used to predict associationship between various physico-chemical parameters and among the metal constituents. We emphasized to study these objectives for a satisfactory period considering current situation of the water body and the transboundary waters by taking into account the water quality flowing through its catchment area. We also observed that many chemical substances emitted into the surrounding environment including the Lake from anthropogenic sources posing threats on the aquatic habitats. The need of the hour is to take tough steps to control the discharge of such pollutants into the lake.

ACKNOWLEDGEMENT:

We are grateful to the Labs of MNIT Jaipur and the Department of ESE, IIT-ISM Dhanbad for technical support and to the Rajasthan Government agencies for permitting us to carry out this study.

REFERENCES:

[1] Patrick Amoatey. Effects of pollution on freshwater aquatic organisms. Water-Environmental Research, 91(10): 1272-1287, https://doi.org/10.1002/wer.1221, 2019.
[2] Kinuthia, G.K., Ngure, V., Beti, D. *et al.* Levels of heavy metals in wastewater and soil samples from open drainage channels in Nairobi, Kenya: community health implication. Sci Rep 10, 8434, https://doi.org/10.1038/s41598-020-65359-5, 2020
[3] Joshua N. Edokpayi, John O. Odiyo and Olatunde S. Durowoju. Impact of Wastewater on Surface Water Quality in Developing Countries: A Case Study of South Africa, Water Quality, Hlanganani Tutu, Intech Open, https://doi.org/10.5772/66561, 2017.
[4] 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.
[5] Chetna Pradhan; 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.
[6] K. P. Sharma, Subhasini Sharma, *et al.* Mansagar Lake: Past, Present & Future" Proceedings of Taal 2007, 1530-1541, 2007.
[7] Singh, Y.; Jain, M.K. Pearson's Correlation and Trend Analysis for Physico-Chemical Parameters of Mansagar Lake, Jaipur. Preprints *2021*, *2021090237*, https://doi.org/10.20944/preprints202109.0237.v1.
[8] 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.
[9] 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.
[10] Rama Pal, R.K. Dubey, S.K. Dubey and A.K. Singh. Assessment of Heavy Metal Pollution through Index Analysis for Yamuna Water in Agra Region, India. Int. J. Curr. Microbiol. App. Sci., 6(12): 1491-1498, https://doi.org/10.20546/ijcmas.2017.612.166, 2017.
[11] Singh, G., Kamal, R.K., (2017). Heavy metal contamination and its indexing approach for groundwater of Goa mining region, India. Appl Water Sci 7: 1479–1485. https://doi.org/10.1007/s13201-016-0430-3.
[12] Sahoo, M.M., et al., (2020). Modified heavy metal pollution index (m-HPI) for surface water quality in river basins" India. Environ Sci Pollut Res 27, 15350–15364.
[13] Bakan, G., BokeOzkoc, H., Tulek, S., and Cuce, H. (2010). Integrated environmental quality assessment of Kızılırmak River and its coastal environment. Turk J Fish Aquat Sc, 10: 453-462.

[14] Rama Pal, R.K. Dubey, S.K. Dubey and A.K. Singh, (2017). Assessment of heavy metal pollution through index analysis for Yamuna water in Agra Region, India. International Journal of Current Microbiology and Applied Sciences ISSN: 2319-7706, 6(12): 1491-1498. https://doi.org/10.20546/ijcmas.2017.612.166.
[15] Tamasi, G., and Cini, R. (2004). Heavy metals in drinking waters from Mount Amiata. Possible risks from arsenic for public health in the province of Siena. Sci Total Environ, 327: 41-51.
[16] Prasad B, Kumari S., (2008). Heavy metal pollution index of groundwater of an abandoned opencast mine filled with fly ash. Mine Water Environ 27(4):265–267.
[17] Prasad B, Mondal KK, (2008). The impact of filling an abandoned opencast mine with fly ash on ground water quality: a case study. Mine Water Environ 27(1):40–45.
[18] Tiwari AK, et al., (2015). Evaluation of surface water quality by using GIS and a heavy metal pollution index (HPI) model in a coal mining area, India" Bull Environ Contam Toxicol 95:304–310.
[19] Bureau of Indian Standards, BIS (2012). Indian Standard drinking water: Specification (2nd Revision). IS 10500: 2012, https://www.indiawaterportal.org/sites/default/files/2020-11/bis_10500-2012_wq_standards_0_0.pdf.
[20] Showqi, I., Lone, F.A. & Naikoo, M., (2018). Preliminary assessment of heavy metals in water, sediment and macrophyte (Lemna minor) collected from Anchar Lake, Kashmir, India. Appl Water Sci 8, 80. https://doi.org/10.1007/s13201-018-0720-z.
[21] Saeed Shanbehzadeh, Marzieh Vahid Dastjerdi, Akbar Hassanzadeh, Toba Kiyanizadeh, (2014). Heavy Metals in Water and Sediment: A Case Study of Tembi River. Journal of Environmental and Public Health, Article ID 858720, Hindawi publication. https://doi.org/10.1155/2014/858720.
[22] Jingxi Ma, Shuqing Wu, N. V. Ravi Shekhar, Supriya Biswas, and Anoop Kumar Sahu, (2020). Determination of physicochemical parameters and levels of heavy metals in food waste water with environmental effects. Bioinorg Chem Appl. 2020: 8886093, https://doi.org/10.1155/2020/8886093.
[23] M. Yerima Kwaya, H. Hamidu, et al., (2019). Heavy Metals Pollution Indices and Multivariate Statistical Evaluation of Groundwater Quality of Maru town and environs. J. Mater. Environ. Sci., 10(1): 32-44. Available at https://www.jmaterenvironsci.com/Document/vol10.
[24] Kumari Sonu, Ishwar Chandra Yadav, Amrendra Kumar and Ningombam Linthoingambi Devi, (2019). Dataset on assessment of heavy metals contamination in multi-environmental samples from Patna, India. Data Brief. https://doi.org/10.1016/j.dib.2019.104079.
[25] Sarala Thambavani D, Uma Mageswari T.S.R., (2013). Metal Pollution Assessment in Ground Water. Bull. Env. Pharmacol. Life Sci., 2 (12): 122-129. Available at http://www.bepls.com/nov_2013/19.pdf
[26] Gong Qingjie, Deng Jun, Xiang Yunchuan, Wang Qingfei, (2008). Calculating pollution indices by heavy metals in ecological geochemistry assessment and a case study in parks of Beijing. Journal of China University of Geosciences, 19(3): 230-241. https://doi.org/10.1016/S1002-0705(08)60042-4.
[27] Zhang J, Zhou F, Chen C, Sun X, Shi Y, Zhao H, et al. (2018) Spatial distribution and correlation characteristics of heavy metals in the seawater, suspended particulate matter and sediments in Zhanjiang Bay, China. PLoS ONE 13 (8): e0201414. https://doi.org/10.1371/journal. pone.0201414.
[28] Dekov V M, Arau´jo F, Grieken R V, Subramanian V., (1998). Chemical composition of sediments and suspended matter from the Cauvery and Brahmaputra rivers. Science of the Total Environment, 212 (2–3): 89–105.
[29] Huang J Z, Ge X P, Wang D S., (2012). Distribution of heavy metals in the water column, suspended particulate matters and the sediment under hydrodynamic conditions using an annular flume. Journal of Environmental Sciences. 24: 2051–2059.