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Evaluation of Water Quality Index Using Various Physico-Chemical Parameters and Correlation Analysis of Gothivali Waterbody, Navi-Mumbai, Maharashtra, India

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Abstract: Water is a necessary component for the survival of all humans and animals, a finite resource in the natural world. Water quality is crucial not only for humans, but also for the plants and animals that rely on it to survive. As a result, water quality must be checked at regular intervals. This study focuses on determining the quality of water of Gothivali Waterbody, Navi-Mumbai using the Weighted Arithmetic Water Quality Index (WQI) and several physico-chemical factors i.e. Temperature, pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (B.O.D.), Chemical Oxygen Demand (C.O.D.), Alkalinity, Electrical Conductivity, Turbidity, Nitrite-Nitrogen, Nitrate-Nitrogen, and Hardness were analyzed in this investigation. The study was compiled into three seasons monsoon, post-monsoon, and pre-monsoon, with the Water Quality Index of the water body being 65.33, 72.20, and 75.06, respectively. WQI in all seasons are as prescribed by Indian Standards, and are acceptable for domestic use. The databases obtained were subjected to Pearson Correlation Matrix Correlation coefficients which revealed positive and significant correlations between the pairs of parameters in surface water. The present study however, is believed to serve as a baseline data for further studies. Future research is needed to provide more information on the seasonal variations of surface water quality.

Keywords: Water parameters, Water quality index, Seasonal variations, Weighted arithmetic, Sampling stations, Physico-chemical factors

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Introduction

Water, a valuable natural resource is the most important component of the ecosystem. Lakes, reservoirs, and wetlands are crucial components of our environment because they help to keep our ecosystem's biological balance in check (Kar *et al*., 2013). In recent decades as a result of fast expanding population, industrialization, and urbanization, Water pollution and contamination have increased which has impacted the availability and quality of water (Bakari, 2014, Prasad *et al*., 2019). Depletion of dissolved oxygen (DO) and addition of organics such as carbon, nitrogen, and other elements, increases the rate of biological activity in the water body (Kannel et al., 2010). As a result, it is critical to assess water quality on a regular basis and device measures to protect it. Physical, chemical, and biological factors can be used to assess the water quality of any specific place or source (Glavan and Pintar, 2010, Maheswaran *et al*., 2015). If these factors' values exceed set limitations, they are detrimental to human health (Tyagi *et al*., 2013). As a result, the suitability of water sources for human use has been described in terms of the Water Quality Index (WQI), which is one of the most effective tools (Yisa and Jimoh 2010, Rao *et al*., 2012, Shrivastava and Thakur, 2018). As a result, it becomes a key criterion for assessing and managing water bodies. WQI is a rating that reflects the combined impact of many water quality factors (Phadatare and Gawande, 2016).

In recent years, a more simple approach based on statistical correlation has been created for comparing physico-chemical parameters utilising mathematical relationships. The water quality distinctiveness of the Ganga in Haridwar were examined using Person's Correlation after extensive research on statistical analysis to determine surface water quality (Joshi *et al*., 2009). Statistical analyses of water's physicochemical parameters have been reported from various locations of India (Bhandari *et al*., 2008, Sharma *et al*., 2009).

In this study an attempt was made to assess the quality of Gothivali water body by analyzing the physico-chemical parameters of water and evaluating the quality of surface water in the study area. A bivariate analysis is used to analyze the correlation studies of several physicochemical characteristics for a water body which specifies the magnitude and direction of the relationship between two variables. Pearson's correlation is a covariance approach that is widely regarded as the finest way for determining the relationship between two continuous variables.

This study was performed to update data, identify the effects of anthropogenic activities on water quality, and discuss the water body's acceptability for human consumption based on computed water quality index values. We have also outlined the calculated association link among examined physico-chemical parameters using Pearson's correlation approach concepts.

Materials and Methods

Study Area: The Gothivali Lake is located in Ghansoli, Navi-Mumbai, Maharashtra (Figs. 1,2). The area of lake is about 2,850 sq.km. The latitude and longitude of lake are 19.1361N and 73.0005E, respectively.

Sample Collection: From June 2019 to March 2020, a monthly water sample was taken from the water body. Clean plastic and glass bottles were used to collect samples from five distinct sampling points (n=5) (Fig. 3). Hydrological analysis of different parameters of water samples such as Temperature, pH, DO, BOD, COD, Alkalinity, Electrical Conductivity, Turbidity, Nitrite-Nitrogen, Nitrate-Nitrogen, and Hardness was carried out as prescribed by APHA (2005) and Trivedi and Goel (1984). The results were complied in three season and used to calculate the WQI.

Water quality index (WQI): The goal of researching water quality index is to determine the quality of water suitable for human consumption. The Indian Council of Medical Research (ICMR), WHO and, Bureau of Indian Standards (BIS) recommended water quality standards were used to calculate water quality. Water quality index was calculated by using the weighted arithmetic index method as described by Chatterjee and Raziuddin (2002), Mohanty (2004), Yadav *et al.* (2010), Ramakrishnaiah *et al.* (2009), and Saeedi *et al.* (2010). The following steps were used to determine the water quality:

Fig. 1: Satellite view of Gothivali Lake.

Fig. 2: Photograph of Gothivali Lake.

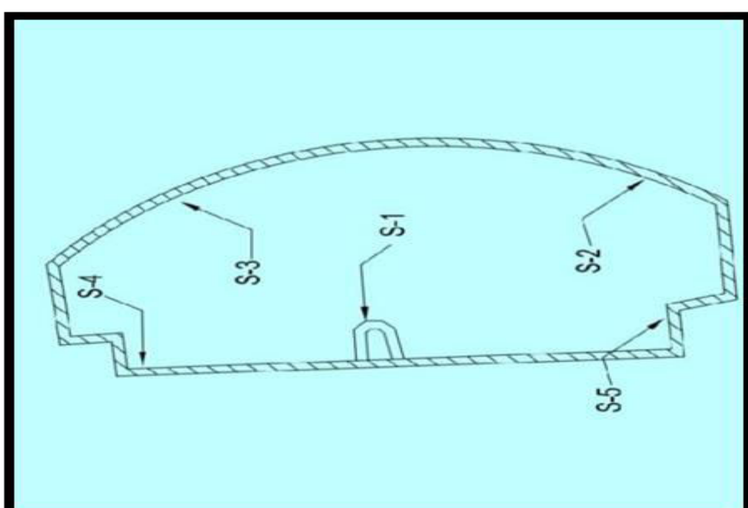

Fig. 3: Sampling stations.

1. To find out the quality rating (Qn): Arithmetic index was calculated using Quality Rating by following expression:

$$Qn = 100\,[Vn-Vio]/[Sn-Vio]$$

Where, n=Water quality parameter, Qn= Quality rating of n^{th} water quality parameter, Vn = Estimated value of n^{th} water quality parameter, Sn = Standard value of n^{th} water parameter, Vio = Ideal weight value of n^{th} parameter in pure water (Vio value is zero for all the parameters except for pH and DO it is 7 and 14.6, respectively)

2: To find out unit weight (Wn): Unit weight was calculated for n^{th} water quality parameter by value inversely proportional to recommended standard value--

$$Wn=K/Sn$$

Where Wn = Unit weight for n^{th} parameter, K= Constant of proportionality, Sn = Standard value of n^{th} water parameter.

$$K = \frac{1}{1/Vs_1 + 1/Vs_2 + 1/Vs_3 + 1/Vs4 \ldots\ldots 1/Vs_n}$$

To calculate the aggregate WQI, mathematical expression WQI was calculated by using following expression:

$$WQI= \sum WnQn/\sum Wn$$

Where, Qn = Quality rating of the n^{th} water quality parameter, Wn = Unit weight for n^{th} parameter

Statistical Analysis:

The mean value and standard deviation, of valuable parameter was calculated. The parameters which showed significant positive and negative correlation common in the water bodies were measured in terms of Pearson's correlation coefficients. To obtain Pearson's product moment coefficient correlation between different physico – chemical parameters coefficient correlation is symbolized as r and is calculated by the following formula:

$$r = \frac{Cov(X,Y)}{\sigma x \sigma y}$$

Where r = correlation coefficient; Cov(X, Y) = Covariance between X and Y; σ_x = Standard deviation of X; σ_y = Standard deviation of Y; X and Y represent two different variables.

The significant correlation has been further verified by using *t*-test.

Results and Discussion

The physicochemical parameters as well as their fluctuations in the three seasons, the results with minimum, maximum , average and standard deviation values are summarized in Tables 1 and 2 and Figures 4a and b and were compared with the standards values recommended by ICMR, WHO and, BIS. In the present study high temperature during pre-monsoon and low temperature in monsoon was observed. Variation in temperature may be due to seasonal differences. The pH of water being an important characteristic, impacts its appropriateness for various applications. pH range of 6.5 to 8.2 is ideal for long-term aquatic life (Sharma *et al*., 2020). Values obtained in the present study is depicted in Tables1 and 2, and Figures 4a and b which are within the prescribed limits (Kangabam *et al*., 2017).

Dissolved oxygen is a component that determines whether aerobic or anaerobic organisms are responsible for biological changes (Gangwar *et al*., 2013).The amount of oxygen required by microorganisms in stabilizing degradable organic matter in a water body is measured by bio-chemical oxygen demand (Gangwar *et al*., 2013). DO in the present study (Tables 1, 2) were found to be high in the post-monsoon period. These observations are in accordance with those of Saksena *et al*. (2008), Gopalkrishna *et al*. (2016), Kangabam *et al*. (2017) and Sharma *et al.* (2017). In the present investigation BOD values were recorded as 4.73 mg/l in post- monsoon, in pre-monsoon and monsoon it was below 5 mg/l (Tables 1, 2). Natural waters with BOD of less than 5 mg/l are considered unpolluted (Shikha *et al*., 2017). Chemical Oxygen Demand (Tables 1, 2) was observed to be low during the three seasons when compared with the value of BIS and ICMR. Alkalinity values recorded in the current investigation during the three seasons were below the permissible limits (Tables 1, 2, Figs. 4a, b). Whereas values for turbidity, Hardness and Electrical conductivity were found to be within the permissible limit when compared to recommendation BIS and ICMR (Tables 1, 2). In this study nitrate and nitrite (Tables 1, 2; Figs. 4a, b) was considerably lower than those reported by Patra *et al*. (2010). Nitrate concentration depends on the activity of nitrifying bacteria which in turn get influenced by presence of dissolved oxygen (Ramesh and Krishnaiah, 2015; Phadatare and Gawande, 2016). Similar observations were earlier reported by Yogendra and Puttaiah (2008), Kumar and Dua (2009), Yadav *et al*. (2010), Satone *et al.* (2011), Sharma *et al*. (2013), Wagh *et al*. (2015), Gopal Krishan *et al.* (2016), Sharma *et al*. (2017, 2020), Behailu *et al*. (2017) and Kinjal and Kapila (2020).

The results of the Water Quality Index were computated during the three season (Table 1). Present study reveals WQI range for the Gothivale water body and classified as Poor in all three season (Tables 3, 4) by using Chatterji and Raziuddin (2002) and Yadav *et al*. (2010) scale. In light of this finding, we categorized the WQI scores using the Ramakrishnaiah *et al*. (2009) and Mohanty (2004) (Tables 3, 4) scales. According to this categorization the water quality of the Gotivale Lake falls into the 'Good' category (Table 3). The current result is identical to earlier findings made by Rai and Raleng (2012), Yadav *et al*. (2010), Sener *et al*. (2017), Shrivastava and Thakur (2018) and Cao Truong Son *et al*. 2020). By combining various criteria into a single number, the index may be easily interpreted, making it a useful tool for management (Shrivastava and Thakur, 2018; Cao Truong Son *et al*., 2020).

Pearson correlation coefficient was computed in order to generate matrix and understand the association and relationship of 11 different physic-chemical parameters (Temperature, pH, DO, BOD, COD, Alkalinity, Electrical Conductivity, Turbidity, Nitrite-Nitrogen, Nitrate-Nitrogen, and Hardness) of the Gothivali lake (Table 5). Data is the mean value of monthly collected samples. SPSS software was used for calculation. For simplicity, we have evaluated the correlation coefficient ‗*r*' up to two decimal values only. The values (r) ranged from r= 0.53 - 0.60, $p < 0.05$ fairly positive significant, r= 0.61--0.65, $p < 0.02$, moderately positive significant, r= 0.66 and above and $p < 0.01$. Highly significant positive correlation. High significant negative correlation for r= 0.66 and above $p < 0.01$.

In the present study, Temp has highly negative co-relation with pH (r=-0.60), COD (r=--0.68), Turbidity (r= --0.69), hardness (r= --0.74), conductivity (r= --0.79), Nitrite (r=--0.70) and nitrate (r= --0.59). This shows that with increase or decrease in Temperature values of pH , COD, Turbidity, hardness, conductivity, Nitrite and nitrate also exhibit decrease or increase. Alkalinity has strong negative correlation with Turbidity (r=--0.57), hardness (r= --0.58) may be due to influx of sewage water, whereas pH shows highly positive significant co-relation with COD (r=0.78), Turbidity (r=0.80), hardness (r=0.86), conductivity (r=0.84), Nitrite (r=0.67) and nitrate (r=0.72) highly negative significant co-relation with Alkalinity (r=--0.67). DO shows highly strong positive significant co-relation with BOD (r=0.80) may be due to algal blooms and fairly positive significant co-relation with Hardness (r=0.55) and highly strong negative co-relation with Alkalinity (r= --0.73). BOD shows highly strong positive significant co-relation with Hardness (r= 0.68), moderately positive significant, with COD (r=0.62) and Turbidity (r= 0.64). COD shows highly significant positive correlation with Turbidity (r=0.90), hardness (r=0.93), conductivity (r=0.95), Nitrite (r=0.95) and nitrate (r= 0.93). Turbidity is strong positive with Hardness (r=0.92), Conductivity (r=0.92), Nitrite(r=0.84) and nitrate (r= 0.87). Hardness is strong positive with conductivity (r=0.94), Nitrite (r=0.89) and nitrate (r= 0.89).

Table 1: Physicochemical parameters and water quality analysis of Gothivali Water body

S. No.	Parameters	Standard values (Sn)	Unit weight (Wn)	MONSOON			POST- MONSOON			PRE-MONSOON		
				Observed value Vn	Quality rating (qn)	Wnqn	Observed value	Quality rating (qn)	Wnqn	Observed value	Quality rating (qn)	Wnqn
1	Temperature	15 (WHO)	0.123	29.5	196.66	26.37	30.5	203.33	25.13	32.5	213.33	24.313
2	PH	6.5-8.5 (ICMR/BIS)	0.219	6.7	100	21.9	7.1	100	21.9	7.25	100	21.9
3	DO mg/l	5.00 (ICMR/BIS)	0.372	6.4	85	31.62	8.63	62.1	23.1	6.67	82.6	30.75
4	B.O.D mg/l	5.00 (ICMR/BIS)	0.372	2.8	56	20.83	4.73	94.6	35.19	3.51	70.2	26.11
5	C.O.D mg/l	10 (WHO)	0.025	4.47	44.7	1.12	6.28	62.8	1.574	7.45	74.5	1.87
6	Total Alkalinity mg/l	120 (ICMR)	0.015	226.5	188.75	2.925	162	135	2.0925	185.8	154.83	2.50
7	Turbidity	5 NTU (BIS)	0.370	4.5	90	33.38	5.42	108.4	40.2	5.9	118	43.76
8	Total Hardness mg/l	300 (ICMR/BIS)	0.006	10	3.33	0.02	13.7	4.56	0.028	14.7	4.9	0.03
9	Conductivity µS/cm	300 (ICMR)	0.006	0.28	0.09	0.0005	0.59	0.19	0.0011	0.84	0.28	0.0017
10	Nitrite Nitrogen µg/l	3 (BIS)	0.616	0.17	5.66	3.489	0.36	12	7.399	0.56	18.66	11.505
11	Nitrate Nitrogen µg/l	45 (ICMR/BIS)	0.041	0.17	0.37	0.015	0.31	0.68	0.0278	0.48	1.06	0.0434
Total			∑Wn= 2.1685			∑Wnq= 141.66			∑Wnqn = 156.58			∑Wnqn= 162.78
Water Quality Index				**65.33**			**72.20**			**75.06**		

Table 2: Statistics Summary of water parameters of Gothivali Water body

	MONSOON			POST- MONSOON			PRE-MONSOON		
	min	max	Avg	min	max	Avg	min	max	Avg
Temperature	30	32	32	28	32	30.5	32	33	32.5
pH	6.5	7.0	6.7	7.0	7.2	7.1	7.1	7.4	7.25
Dissolved Oxygen mg/l	5.7	6.92	6.4 ±1.06	8.1	9.5	8.63±.61	6.42	7.52	7.04 ±0.48
B.O.D. mg/l	2.71	2.94	2.82±0.10	3.62	5.53	4.73±0.82	3.28	3.54	3.4075±0.13
C.O.D. mg/l	4.29	4.81	4.47±0.24	5.6	6.94	6.28±0.73	6.84	8.06	7.45±0.86
Total Alkalinity mg/l	169	298	226.5±61.8	106	191	162±38.0	182	189.6	185.8±5.37
Turbidity	4.3	4.8	4.5±0.24	4.78	5.72	5.42±0.43	5.52	5.98	5.9±0.11
Total Hardness mg/l	8.96	10.6	10.0±0.73	13.3	14.6	13.7±0.59	14.26	15.2	14.7±0.70
Conductivity µS/cm	0.22	0.38	0.28±0.07	0.42	0.76	0.59±0.13	0.83	0.86	0.84±0.02
Nitrite Nitrogen µg/l	0.13	0.24	0.17±0.05	0.32	0.43	0.36±0.05	0.48	0.64	0.56±0.11
Nitrate Nitrogen µg/l	0.14	0.2	0.17±0.02	0.28	0.35	0.31±0.02	0.42	0.55	0.48±0.09

Table 3: Comparative Water quality Scale

S. No.	Water quality	WQI Mohanty (2004)	WQI Ramakrishnaiah *et al*. (2009)	WQI Yadav *et al.* (2010)	Chatterji and Raziuddin (2002)
1	Excellent water	<50	<50	0-25	0-25
2	Good water	50–100	50–100	26-50	26-50
3	Poor water	100–200	100–200	51-75	51-75
4	Very poor water	200–300	200–300	76-100	76-100
5	Water unsuitable for drinking purpose	>300	>300	100 and above	100 and above

Table 4: Water quality indices in different season of Gothivali water body

	WQI values	Water quality based on scale			
		Mohanty (2004)	Ramakrishnaiah *et al.* (2009)	Yadav *et al.* (2010)	Chatterji and Raziuddin (2002)
Monsoon	65.33	Good	Good	Poor	Poor
Post monsoon	72.20	Good	Good	Poor	Poor
Pre monsoon	75.06	Good	Good	Poor	Poor

Table 5: Correlation table for physicochemical parameters at Gothivale Water body

	Temp	pH	DO	B.O.D	C.O.D	Alkalinity	Turbidity	Hardness	Cond	Nitrite	Nitrate
Temp	1										
pH	*-0.60	1									
DO	-0.08	0.505	1								
B.O.D	-0.50	0.53	***0.80	1							
C.O.D	**-0.68	***0.78	0.41	**0.62	1						
Alkalinity	0.10	*-0.67	*-0.73	-0.53	-0.51	1					
Turbidity	***-0.69	***0.80	0.44	**0.64	***0.90	*-0.57	1				
Hardness	***-0.74	***0.86	*0.55	***0.68	***0.93	*-0.58	***0.92	1			
Conductivity	***-0.79	***0.84	0.33	*0.59	***0.95	-0.50	***0.92	***0.94	1		
Nitrite	***-0.70	***0.67	0.24	0.49	***0.95	-0.27	***0.84	***0.89	***0.90	1	
Nitrate	*-0.59	***0.72	0.26	0.40	***0.93	-0.42	***0.87	***0.89	***0.90	***0.96	1

Highly significant negative correlation r= 0.66 and above, fairly significant positive correlation r= 0.53—0.60 p <0.05 (*) moderately significant positive correlation r= 0.61--0.65 p<0.02(**)

Highly significant positive correlation, r= 0.66 and above (***) and p <0.01

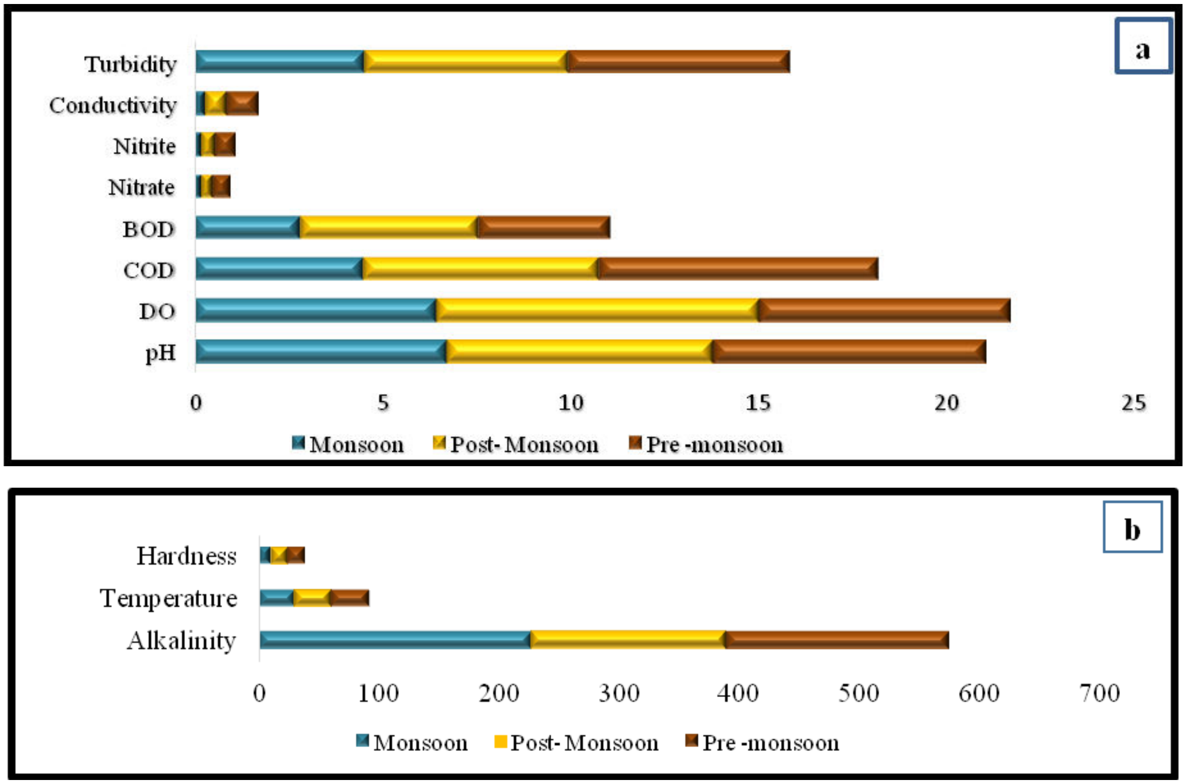

Fig. 4a, b: Physiochemical parameter for Gothivali water body during the three seasons (Monsoon, Post- monsoon and Pre- monsoon).

Conclusion

The most generally used approaches, single-factor methods, give useful information in water quality analyses of the Gothivali water body. The calculated WQI indicates that the water sample is in good condition. All physico-chemical variables in the Gothivali water body are within WHO's recommended limits. 9 parameters out of 11 have positive co-relation, The findings of this physico-chemical investigation could aid in the management of the lake's water quality. Continuous monitoring is essential in the future to safeguard water from contamination caused by increasing industrialization. Because no data on this significant lake has been published, the data acquired in this sudy could be utilized as a baseline and reference point when considering future changes induced by nature or man in this water body. The correlation analysis of water quality metrics shows that all parameters are more or less connected with one another.

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