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Suitability Analysis of Water in an Urban Tropical Lake Using Seasonal Water-Quality Index

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Suitability Analysis of Water in an Urban Tropical Lake Using Seasonal Water-Quality Index

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Abstract
This study deals with the study of water-quality index (WQI) of a tropical, urban water body in Gorakhpur region (India). Water-quality index was determined on the basis of various physico-chemical parameters like pH, temperature, total solids, total dissolved solids, total suspended solids, dissolved oxygen, biological oxygen demand, hardness, calcium, magnesium, etc. Then, on the basis of calculated WQI, the water was correlated for its use for public consumption, recreation, or any other purpose. A number of parameters directly regulate the utility of water for a particular purpose. The water-quality index obtained for the water body in different seasons of study periods, i.e., rainy season, winter season, and summer season are 78.29, 74.01, and 116.94, respectively; this indicates the water quality of the collected samples to be very poor.

Keywords: Water quality index; Physico-chemical analysis; Seasonal variation; Farenda; Gorakhpur.

1. INTRODUCTION

Water-quality index provides a single numerical value that expresses overall water quality at a certain location and time, based on several water-quality parameters. The objective of water-quality index is to turn complex water-quality data into information that is understandable for use by the public, according to [1]. However, a water-quality index based on some very important parameters can provide a simple indicator of water quality. In general, water-quality indices incorporate data from multiple water-quality parameters into a mathematical equation that rates the health of a water body with the form of a numerical figure.

As per United Nations Environmental Programme (UNEO), as many as two billion people depend directly upon aquifers for drinking water, and 40% of the world food is produced by irrigated agriculture that relies largely on ground water [2]. However, the rapid pace of agricultural development, industrialization, and urbanization has resulted in the over-exploitation and contamination of ground-water resource in parts of the country, resulting in various adverse environmental impacts and threatening it's long term sustainability [3]. The fresh water is of vital concern for mankind, since it is directly linked to human welfare. The surface water bodies, which are the most important sources of water for human activities are unfortunately under severe environmental stress and are being threatened as a consequence of developmental activities [4]. With population growth and rising affluence, the need for food and thus agricultural water for irrigation is increasing. At the same time, the quantity of water with sufficient quality is declining. This degradation in water quality is affecting the life of the flora as well as that of the aquatic fauna [5]. There is also an increasing demand to shift more of the water used in agriculture to higher-value urban and industrial uses. It is with this background, the present work was undertaken between April 2011 and March 2012, to investigate the water-quality suitability for different purposes.

2. MATERIALS AND METHODS

Water samples were collected monthly from Faren Nala, receiving the effluent from Saraya sugar mill, Gorakhpur. The collected water samples were subjected for the analysis of physico-chemical parameters. The parameters pH, temperature, total solids, total dissolved solids, total suspended solids, dissolved oxygen, biological oxygen demand, chloride, hardness, calcium and magnesium were analyzed in the laboratory as per the standard procedure of [6]. The WQI can be used to monitor water-quality changes in a particular water supply over time lapse, or it can be used to compare a water supply quality with other water supplies in the region or from around the world. The concept of indices to represent gradation in water quality was first proposed by [7]. It indicates the quality by an index number, which represents the overall quality of water for any intended use. The result can be used to determine if a particular stretch of water is considered as healthy.

In this study, for the calculation of water-quality index, twelve important parameters were selected. The WQI has been compared by using the standards of drinking-water quality recommended by the World Health Organization [8], Bureau of Indian Standards [9], and Indian Council for Medical Research, and the prescribed standards is given in Table 1. The weighted arithmetic index method has been used for the calculation of WQI of the water body. Further, the quality rating or sub index

Table 1: Drinking-water standards, recommended agencies, and unit weights. (All values except pH are in mg/L.)

Sr. No.	Parameters	Standards	Recommended agencies	Unit weights
1.	pH	6.5-8.5	ICMR/BIS	0.2190
2.	Tem (°C)	72°C	ICMR	0.1
3.	Turbidity (NTU)	10	ICMR	0.09
4.	TS (mg/L)	500	ICMR/BIS	0.08
5.	TDS (mg/L)	500	ICMR/BIS	0.0037
6.	TSS (mg/L)	500	ICMR/BIS	0.0037
7.	DO (mg/L)	5.0	ICMR/BIS	0.3723
8.	BOD (mg/L)	5.0	ICMR/BIS	0.3723
10.	Hardnesss (mg/L)	300	ICMR/BIS	0.0062
11.	Chloride (mg/L)	250	ICMR	0.0074
12.	Calcium (mg/L)	75	ICMR/BIS	0.025
13.	Magnesium (mg/L)	30	ICMR/BIS	0.061

Table 2: Water-quality index (WQI) and the status of water quality [1].

Water-quality index level	Water quality status
0-25	Excellent water quality
26-50	Good water quality
51-75	Poor water quality
76-100	Very poor water quality
>100	Unsuitable for consumption

(q_n) was calculated using the following expression. The calculated values were correlated for water quality (Table 2), as given by [1]. WQI was calculated by the formula given below:

$$q_n = 100[V_n\text{-}V_{io}]/[S_n\text{-}V_{io}]$$

where,
q_n = quality rating for the nth water-quality parameter
V_n = estimated value of the nth parameter at a given sampling station
S_n = standard permissible value of the nth parameter.
V_{io} = ideal value of nth parameter in pure water (i.e., 0 for all other parameters except the parameter pH and dissolved oxygen [7.0 and 14.6 mg/L, respectively])

Unit weight was calculated by a value inversely proportional to the recommended standard value Sn of the corresponding parameter.
$W_n = K/S_n$
W_n = unit weight for the nth parameters.
S_n = standard value for nth parameters.
K = constant for proportionality.
The overall water-quality index was calculated by aggregating the quality rating with the unit weight linearly.

$$\mathbf{WQI} = \sum \mathbf{q_n W_n} / \sum \mathbf{W_n}$$

3. RESULTS AND DISCUSSION

Variation of different parameters as in different seasons is expressed in Table 3. Water-quality analysis was conducted on a monthly basis, but the seasonal statistics of rainy, winter, and summer seasons is expressed in the Tables 4-6, respectively.

The comparative study of physico-chemical parameters' variations observed during the different seasons of the study shows the noxious behavior of the water samples. Among all the physico-chemical parameters selected for the water-quality index calculations, the pH is an important parameter which determines the suitability of water for various purposes [4]. In the

Table 3: Seasonal variation of the physico-chemical parameters of the water sample.

Sr. No.	Parameters	Rainy season	Winter season	Summer season
1.	pH	7.95	7.4925	7.6375
2.	Tem (°C)	24.45	23.9	28.15
3.	Turbidity (NTU)	1.85	1.7	1.5
4.	TS (mg/L)	1,013.75	941.25	861.25
5.	TDS (mg/L)	707.5	688.75	620
6.	TSS (mg/L)	306.25	255	241.25
7.	DO (mg/L)	4.675	4.725	4.85
8.	BOD (mg/L)	1.575	2.25	2.325
9.	Hardnesss (mg/L)	415	368.75	366.5
10.	Chloride (mg/L)	140.075	132.65	186.375
11.	Calcium (mg/L)	182.5	184	190.5
12.	Magnesium (mg/L)	56.5	44.715	42.7625

Table 4: Water-quality index of water sample in rainy season.

Sr. No.	Parameters	Rainy season	Standard values	Unit weight (Wn)	Quality range qn	Wn * qn
1.	pH	7.95	6.5-8.5	0.2192	63.33333	13.88267
2.	Tem (°C)	24.45	72	0.1	33.95833	3.395833
3.	Turbidity (NTU)	1.85	10	0.09	18.5	1.665
4.	TS (mg/L)	1,013.75	500	0.08	202.75	16.22
5.	TDS (mg/L)	707.5	500	0.0037	141.5	0.52355
6.	TSS (mg/L)	306.25	500	0.0037	61.25	0.226625
7.	DO (mg/L)	4.675	5	0.3723	103.3854	38.49039
8.	BOD (mg/L)	1.575	5	0.3723	31.5	11.72745
9.	Hardnesss (mg/L)	415	300	0.0062	138.3333	0.857667
10.	Chloride (mg/L)	140.075	250	0.0074	56.03	0.414622
11.	Calcium (mg/L)	182.5	75	0.025	243.3333	6.083333
12.	Magnesium (mg/L)	56.5	30	0.061	188.3333	11.48833
				∑ Wn = 1.3408	∑ qn = 1,282.207	∑ Wnqn = 104.9755
Water-Quality Index = ∑Wnqn/∑Wn = 78.29						

Table 5: Water-quality index of water sample in winter season.

Sr. No.	Parameters	Winter season	Standard values	Unit weight (Wn)	Quality range qn	Wn * qn
1.	pH	7.4925	6.5-8.5	0.2192	32.83333	7.197067
2.	Tem (°C)	23.9	72	0.1	33.19444	3.319444
3.	Turbidity (NTU)	1.7	10	0.09	17	1.53
4.	TS (mg/L)	941.25	500	0.08	188.25	15.06
5.	TDS (mg/L)	688.75	500	0.0037	137.75	0.509675
6.	TSS (mg/L)	255	500	0.0037	51	0.1887
7.	DO (mg/L)	4.725	5	0.3723	102.8646	38.29648
8.	BOD (mg/L)	2.25	5	0.3723	45	16.7535
9.	Hardnesss (mg/L)	368.75	300	0.0062	122.9167	0.762083
10.	Chloride (mg/L)	132.65	250	0.0074	53.06	0.392644
11.	Calcium (mg/L)	184	75	0.025	245.3333	6.133333
12.	Magnesium (mg/L)	44.715	30	0.061	149.05	9.09205
	WQI			∑ Wn = 1.3408	∑ qn = 1178.252	∑ Wnqn = 99.23498
Water-Quality Index = ∑Wnqn/∑Wn = 74.01						

Table 6: Water-quality index of water sample in summer season.

Sr. No.	Parameters	Summer season	Standard values	Unit weight (Wn)	Quality range qn	Wn * qn
1.	pH	7.6375	6.5-8.5	0.2192	42.5	9.316
2.	Tem (°C)	28.15	72	0.1	10.60764	1.060764
3.	Turbidity (NTU)	1.5	10	0.09	281.5	25.335
4.	TS (mg/L)	861.25	500	0.08	0.3	0.024
5.	TDS (mg/L)	620	500	0.0037	172.25	0.637325
6.	TSS (mg/L)	241.25	500	0.0037	124	0.4588
7.	DO (mg/L)	4.85	5	0.3723	101.5625	37.81172
8.	BOD (mg/L)	2.325	5	0.3723	97	36.1131
9.	Hardnesss (mg/L)	366.5	300	0.0062	0.775	0.004805
10.	Chloride (mg/L)	186.375	250	0.0074	146.6	1.08484
11.	Calcium (mg/L)	190.5	75	0.025	248.5	6.2125
12.	Magnesium (mg/L)	42.7625	30	0.061	635	38.735
	WQI			$\sum$ Wn = 1.3408	$\sum$ qn = 1860.595	$\sum$ Wnqn = 156.7939
Water-Quality Index = $\sum$Wnqn/$\sum$Wn = 116.94						

present study, pH ranged between 7.49 and 7.95. In many of the collections, the pH remained exactly neutral. However, when the average values for three seasons are taken into account, the water sample was found to be slightly alkaline. Other scientists [10-13] have also made similar observations in their studies on different water bodies. TDS and TSS were also found to be very high. Season wise it is found to be high during summer season.

Chloride is one of the most important parameters in assessing the water quality [3]. Munawar [14] is of the opinion that higher concentrations of chlorides indicate a higher degree of organic pollution. In the present study, the concentration of chloride fluctuated between 132.65 and 186.37 mg/L. Seasonally, chloride was found to be high during summer season and low during rainy season. A similar observation has been recorded in several other works also [4, 13].

The concentration of dissolved oxygen regulates the distribution of flora and fauna. The present investigation indicated that the concentration of dissolved oxygen fluctuated between 4.67 and 4.85 mg/L. Seasonally, the concentration of dissolved oxygen was more during summer and least during rainy season. This observation is in conformity with the observation of Reddy *et al.* [15], Ghosh and George [5], and Shashi *et al.* [16].

BOD is a parameter to assess the organic load in a water sample. Many researchers have recorded higher BOD values in polluted water [17]. The BOD concentration ranging between 1.575 and 2.325 mg/L indicated the fact that the water sample is eutrophic. Seasonally, it was high during summer and low in rainy season.

From the foregoing observations of the physico-chemical parameters, it can be concluded that the water sample shows the characters of eutrophication. A relatively higher concentration of chlorides indicates the unsuitability of water for domestic use. Hence, the application of water quality–index technique for the overall assessment of the water quality of a water sample is a useful tool.

This water quality–rating study clearly shows that, the status of the water sample is eutrophic, and it is unsuitable for the human use. It is also observed that the pollution load is relatively high during summer season as compared to the winter and rainy seasons.

WQI during winter season is found to be 78.2; as per Table 1, this water is of very poor quality. At the same time, the WQI of rainy season is 74.01, indicating the water to be of poor quality. However, the value of WQI during summer is 116.94; this indicates that the water samples collected during summer are not fit for any type of use. At the end, this can be concluded that the same source of water cannot be of same quality, round the year; its suitability must be calculated through WQI before using it.

Author Contributions

Both the authors contributed equally in conceiving and designing the study, collecting the data, analyzing the data, and preparing the manuscript.

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Conflict of Interest

None.

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