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Analysis of Water Quality of a Lentic Water Reservoir of Arrah, Bihar (India) by Application of the Water Quality Index (WQI)

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

The water quality index (WQI) is a dimensionless number using arbitrary grading curves to normalize values by combining various characteristics of water quality water into a single value. It has been utilized traditionally to evaluate the water quality for rivers, streams, lakes, and other water sources. So the purpose of the current investigation is to evaluate the WQI of a lentic water body in Arrah (Bihar). For the three seasons' WQI calculations i.e. Monsoon, winter and summer, physico-chemical variables were tracked. For calculating WQI ten physico-chemical parameters were recorded. pH ranges between 7.54-7.86, total alkalinity from 112-167, total hardness 70-160, TDS 325-487, Calcium 43-67, Magnesium 26-130, Chloride 30-52, Sulphate 16-36, DO 5.2-5.7 and Nitrate from 21-34.

The permitted levels were met for the variables total hardness, pH, TDS, Calcium, Dissolved Oxygen, Chloride, Nitrate and Sulphate. On the other hand, the values of total alkalinity were higher in the winter and summer seasons, and the value of magnesium in the summer season was higher than prescribed by Indian Standards.

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1. INTRODUCTION

Water is necessary for all socioeconomic development as well as for the preservation of thriving ecosystems. As the population grows and growth necessitates larger allocations of groundwater and surface water for household agriculture and the industrial sector, the demand on water resources increases, creating tensions, disputes between users, and undue pressure on the environment. It is quite concerning because freshwater resources are under more and more stress due to rising demand, wasteful use, and global pollution.

Over seven billion people, out of the expected 9.3 billion people in the global world, are predicted to have a water scarcity situation, and of them, 40% would experience an extreme water crisis. India's situation is slightly worse because we only have 2.45% of the planet's landmass, which supports 16% of the worldwide people, and we have freshwater resources that do not exceed 4% of the world's total water resources [1]. And apart from availability, ongoing water pollution from sewage, industrial, and mining waste disposal threatens to reduce the amount of readily available usable water, and an increasing percentage of our ground and surface water resources, including lakes, ponds, and rivers, are being classified as polluted [2-5].

To establish understanding of the aquatic environment, data from routine measurements of physico-chemical, and biological characteristics are determined by monitoring water quality. Unfortunately, it does not provide a complete review of the health of water quality. Additionally, it needs to be translated into a format that can be clearly comprehended and successfully interpreted. The WQI create a mathematical equation from data from different variables of water quality and assign only one value to represent the health of the aquatic body. Knowing whether or not water is suitable for specific applications requires careful assessment of its WQI [6]. WQI is a mathematical formula that converts several water quality data into a single numeric value [7-9]. The single number relies on relative scales that classify water quality from very bad to excellent [10]. WQI additionally allows for the evaluation of patterns and alterations in water quality. The quality and potential uses of any body of water are clear and simple for decision-makers to understand. Lentic water can be categorized for suitability of various purposes based on the results of WQI [11,12]. In the public domain, some WQI methods have been frequently used to measure water quality [13]. US NSFWQI [14,15], BCWQI [16], Oregon water quality index, QWQI [11]. FWQI are water quality indices that are widely used throughout the world. In 1970, the National Sanitation Foundation (NSF) developed a broadly utilized water quality Index [14].

In order to determine if the water is polluted or not, the water quality index will be measured. Several researchers have examined the WQI of ponds and lakes Viz., Shardendu and Ambasht [17], Yogendra and Puttaiah [18].

The Water Quality Index is important in the management of water resources and offers a more accessible methodology for expressing water quality [19,20].

Table 1. WQI ranking Index

Water quality grade	Water quality assessment
0 – 25	Excellent
26 – 50	Good
51 – 70	Poor
76 – 100	Very poor
≻ 100	Unsuitable

Any aquatic system's physico-chemical characteristics, which are crucial for evaluating the Condition of natural water in terms of structure and functionality .For assessment of biodiversity WQI for biodiversity is the best measurement tool. WQI is directly correlated to faunal diversity and any degradation in WQI can cause loss of biodiversity. Because lentic water bodies are the primary source of water for drinking, agriculture, farming of fishes, and the aquaculture industry. The entry of contaminants into these bodies of water might lead to bioaccumulation and biodiversity threats [21].

Anthropogenic activities, such as harmful chemicals, eutrophication, changes in land use, and even climate change, have a direct impact on aquatic ecosystems [22]. Poor water quality has an impact on the fish farming sector and can result in lower economic benefits, lower-quality products, and an increased threat to human health [23].

Fig. 1. Study area of the present investigation

Since plankton develop swiftly and react to changes in physico-chemical and biological parameters quickly, zooplanktons are the main consumers of an aquatic environment [24].

Large varieties and number of aquatic insects are of great ecological importance in an aquatic habitat. In a fresh water habitat, aquatic insects are widely considered to be the main macro invertebrate, and they are significant both ecologically and economically. Besides this, the Dipteran Larvae might be used as farm fish food [25]. Several insects are significant human disease carriers and extinction of aquatic insects due to poor WQI may affect the entire population because they provide as a key source of food for the fish and invertebrate populations. Aquatic insects play a significant role in the analysis of WQI due to their prominence in the food chain. Several aquatic insects populations are scavengers and saprophagous, and their extinction might lead to increased water pollution, which would then have an impact on other species of fauna because of the severity of the pollution.

The present investigation is done on a lentic water body of Arrah, Bihar (India).It is a man-made pond located at 25.5617° N, 84.6620° E. It is also popularly known as Chatth pond as a religious indication; holy dip is taken, and pujas are performed with the thought of gaining punya (divinity) and removing Karma. . And indeed now these are the ones spreading contagious illness. It is required to assess the water quality using fundamental approaches to see if it satisfies with water quality standards.

2. MATERIALS AND METHODS

Using the established producers, a 15-day interval was chosen to sample the pond's water, which was subsequently examined for ten physico-chemical parameters. At the sampling location, pH and dissolved oxygen levels were measured, and other variables were assessed in the lab using APHA-recommended standards [26]. Using the drinking water quality criteria suggested by the weighted arithmetic index approach, the WQI of the pond has been measured. Using the following expression, a further quality rating or sub-index (qn) was obtained.

$$q_n = 100 \times [V_n - V_o] / [S_n - V_o]$$

Where,

q_n = Quality score for the n^{th} water quality parameter..
V_n = Estimated value for the n^{th} parameter for a particular sampling area
S_n = Standard permissible value of the n^{th} parameter
V_o = Optimal value of the n^{th} parameter in pure water

A value inversely correlated to the suggested standard values based on the relevant parameters was used to determine unit weight.

$$W_n = K / S_n$$

Where,

W_n = the nth parameter's unit weight

S_n = the nth parameter's standard value
K = a proportionality constant

By linearly aggregating the quality rating with the unit weight, the overall Water Quality Index (WQI) was determined.

$$WQI = \sum q_n W_n / \sum W_n$$

3. RESULTS AND DISCUSSION

From 10 significant sampling sites, the pond's water quality index is calculated. Table 3 shows the seasonal values of several physico-chemical fluctuations and WQI. During the study period, the pond water system's water quality index ranges from 76 to 100, indicating extremely low water quality.

The fluctuations in the physicochemical parameters noticed across the several seasons of the study period were used to determine the WQI values for the pond.

The pH of water is a crucial factor in determining its appropriateness for a wide range of applications. The average pH values were 7.6, 7.5 and 7.8 during the rainy, winter & summer season respectively and were within the ICMR standards. Yet, when the average readings for those seasons are taken into consideration, the water body is found to be somewhat alkaline. Similar observations were also made by Swarnlatha and Narsinga Rao [28], Sinha (1995), Yogendra and Puttaiah [18], Deepa et al. [29], Ajayan and Kumar [30] and Luharia et al. [31]. Vitamin production in the human body ceases when the pH level falls below 6.5. Water tastes saltier as the pH rises above 8.5; this may cause skin damage and eye irritation [32].

The concentration of dissolved solids (organic and inorganic) in water is used to calculate TDS. Any change in the equilibrium of ionic concentration due to human activity has negative repercussions [33]. A rise in TDS raises the visual colour of water, raises water temperature, and inhibits photosynthesis. TDS was found to be high, a maximum of 487 mg/c in the summer.

The average total alkalinity value observed indicated that the water was harsh. Alkalinity in natural waters results from carbon dioxide dissolving in the water [34]. The additional free CO_2 produced by decomposition may be the cause of the higher alkalinity readings during the summer (167 mg/L), whereas the lower readings during the rainy season (112 mg/L) may be the result of dilutions.

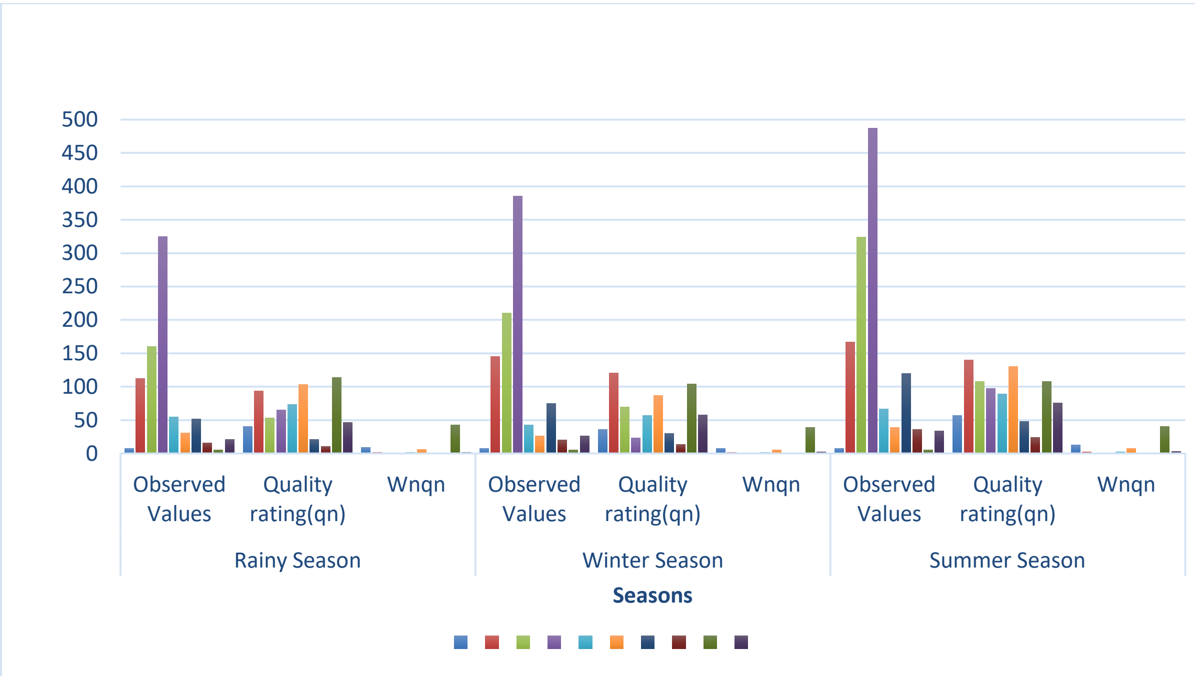

Fig. 2. Water quality index for three different seasons

Table 2. Agency standard for unit weight and drinking water requirements (All values except pH are in mg/L)

Parameters	Standards	Recommended	Unit Weight (W_n)
pH	6.5 – 8.5	ICMR / BIS	0.218
Total Alkalinity	120	ICMR	0.015
Total Hardness	300	ICMR / BIS	0.006
TDS	500	ICMR / BIS	0.003
Calcium	75	ICMR / BIS	0.025
Magnesium	30	ICMR / BIS	0.061
Chloride	250	ICMR / BIS	0.007
Sulphate	150	ICMR / BIS	0.012
Dissolved Oxygen	50	ICMR / BIS	0.372
Nitrate	45	ICMR / BIS	0.041
			$\sum W_n$ = 0.763

Table 3. Season-wise values of Physico-chemical parameters and WQI

Parameter	Monsoon			Winter			Summer		
	Observed Values	Quality rating(q_n)	W_nq_n	Observed Values	Quality rating (q_n)	W_nq_n	Observed Values	Quality rating (q_n)	W_nq_n
pH	7.61	40.66	8.89	7.54	36	7.87	7.86	57.33	12.54
Total Alkalinity	112	93.33	1.44	145	120.83	1.87	167	139.66	2.16
Total Hardness	160	53.33	0.33	210	70	0.43	324	108	0.66
TDS	325	65	0.24	385	23.33	0.08	487	97.4	0.36
Calcium	55	73.33	1.83	43	57.33	1.43	67	89.33	2.23
Magnesium	31	103.33	6.30	26	86.66	5.28	39	130	7.93
Chloride	52	20.8	0.15	75	30	0.22	120	48	0.35
Sulphate	16	10.66	0.13	20	13.33	0.16	36	24	0.29
DO	5.7	114	42.44	5.2	104	38.71	5.4	108	40.20
Nitrate	21	46.66	1.92	26	57.77	2.38	34	75.55	3.12
			$\sum W_nq_n$ =63.70			**$\sum W_nq_n$** = 58.48			**$\sum W_nq_n$**= 69.88
	WQI=83.43			WQI=76.59			WQI=91.52		

Table 4. Based on the WQI score, classification of the properties of water (Ramakrishnaiah et al 2009, Ketata-Rokbani et al 2011 [27])

Range 0f WQI	Class	Water quality
< 50	I	Excellent
50.1-100	II	Good
100.1-200	III	Poor
200.1-300	IV	Very Poor
> 300	V	unsuitable for drinking

Higher alkalinity results during the summer may be due to the presence of extra free CO2 introduced on by decomposition. (167 mg/L), whereas dilutions may be the cause of lower values during the rainy season (112 mg/L) [28]. The observed average total hardness value ranged from 160 mg/L in the monsoon to 210 mg/L in the winter and 324 mg/L in the summer. Low water levels, rapid rate of evaporation, addition of calcium and magnesium salts and other factors might be utilized to explain a higher value. Magnesium and Calcium levels peaked in the summer, 67 mg/L and 39 mg/L, respectively. Peoples that have never experienced it may have a laxative effect from magnesium hardness, especially when combined with the sulphate ion.

One of the most significant factors in determining the quality of water is chloride. Because there is a considerable amount of organic waste of an animal origin, the highest chloride concentration is an indication of pollution. The chloride value obtained in the study was 52, 75, 120 mg/L in the monsoon, winter and summer seasons respectively.

Aquatic flora and fauna are distributed according to oxygen concentrations in the water. This was in close accordance with observations of Shukla [35] in Mohan Ram Pond in Shahdol District, Madhya Pradesh, India. The value of the Water Quality Index is highly influenced on DO. Dissolved Oxygen level is related to the clearness of the water. Compared to unclear water, Clearwater exhibits more DO [36]. The present investigation indicates the highest 5.7 mg/L in the monsoon, 5.4 mg/L in summer & 5.2 mg/L in winter.

In an ecosystem, nitrate is the most essential nutrient. It is recorded 21, 26 and 34 mg/L during monsoon, winter and summer season respectively and exhibit concentration significantly below permissible thresholds. If present in small amounts the taste of water is unaffected by the sulphate ion., and the observed sulphate concentration is quite low in comparison to recommended levels.

4. CONCLUSION

According to the physicochemical parameters of the existing water body it can be concluded that it exhibits greater values for some of pond water characteristics .It has been noted that the pollution load is comparatively higher in the summer than it is in the winter and monsoon seasons. Greater WQI readings clearly illustrate the eutrophic state of the water bodies. In order to improve the quality, some effective steps must be taken, along with the progression of a practical plan for the management of the water quality in the area.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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