APPLICATION OF OVERALL INDEX OF POLLUTION AND WATER QUALITY INDEX FOR A COMPARATIVE ASSESSMENT OF THE WATER QUALITY OF RANI-POND AND SURAJKUND, AURANGABAD, BIHAR, INDIA

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Abstract

An attempt was made to compare the water quality of Rani-Pond and Surajkund, Aurangabad using the overall Index of Pollution and Water Quality Index from March-June2023. Water temperature, pH, electrical conductivity, dissolved oxygen, biochemical oxygen demand, total alkalinity, hardness, total dissolved solids, chloride, nitrate, and turbidity were all calculated using standard methods. The overall Index of Pollution and Water Quality Index were calculated by comparing these values to the standard. According to this observation, there are significant differences in the parameters of the two ponds. Dissolved oxygen, total alkalinity, turbidity, electrical conductivity, and total dissolved solid (in Rani Pond) were all found to be above standard limits. The values 2.3-3.35 of the overall Index of Pollution estimated that the water of Rani-Pond and Surajkundi were slightly polluted (C4) during the summer season. The Water Quality Index with turbidity classified the pond water as poor to unsuitable for use, while the Index without turbidity classified it as good for use.

The study emphasises the importance of using water quality indices that indicate the total effect of ecological factors on surface water quality and provides a simple interpretation of monitoring data to assist local people in improving water quality, implementing proper management policies, and conserving these water bodies.

Keywords: Overall Index of Pollution, Water Quality Index, Physico-chemical parameters, Rani Pond, Surakund, India.

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INTRODUCTION

Surface water bodies are a fundamental resource for meeting all types of human needs; however, the water quality of those resources is currently under severe environmental stress and threat due to various types of anthropogenic activities, and thus the situation is more pathetic in lentic water bodies such as ponds, ditches, reservoirs, lakes etc.[1] Ponds, on the other hand, play a dual role in rejuvenating the surface and subsurface by storing water on the surface and transmitting it to the subsurface. Ponds are categorized into artificial or natural water bodies. The pond water is used for a variety of purposes, including irrigation, bathing, washing, and animal drinking. Most of the cities and towns have developed in and around the bank of the pond because of the multipurpose use of pond water.

The Overall Index of Pollution was developed to assess the quality of surface water.[2] The information of various qualities indicating parameter data could be aggregated into an overall index known as the water quality index to get a better picture of water quality.[3]

The water quality index is one of the most effective tools for communicating water-quality information to concerned citizens and policymakers. It is defined as "a mathematical instrument capable of converting massive amounts of water quality information into a single number, thereby providing a simple and understandable tool for managers and decision-makers on the quality and potential uses of a given water body".[4]

Many researchers have carried out studies on water quality assessment using WQIs around the world as well as in India in various lentic and lotic water bodies.[5-15] However, no literature reveals a study conducted on the water quality index from Aurangabad, which is currently considered a part of the red corridor. Furthermore, the Overall Index of Pollution has not been used in the evaluation of water quality in lentic water bodies in Bihar.

The objective of this study was to use the Overall Index of Pollution and Water Quality Index to assess a comparative account of variation in the water quality status of the Rani-Pond and Surajkund in Aurangabad, Bihar, India during the summer season. This research will aid in the assessment and periodic monitoring of water quality to develop proper management strategies to reduce water pollution despite rising anthropogenic activity.

MATERIAL AND METHODS

Study area

Aurangabad, Bihar, India (Figure 1) is located between the coordinates 24·7033^{0}N and 84.3542^{0}E. During the summer, temperatures can reach 40°C to 50°C. Deo is a historical site located 18 km southeast of Aurangabad, between the coordinates 24.6561^{0}N and 84.4356^{0}E. As a historical site, the city has many perennial water bodies such as Surajkund, Rani Pond and Surya Mandir etc. Rani-Pond and Surajkund are among the highest scorers.

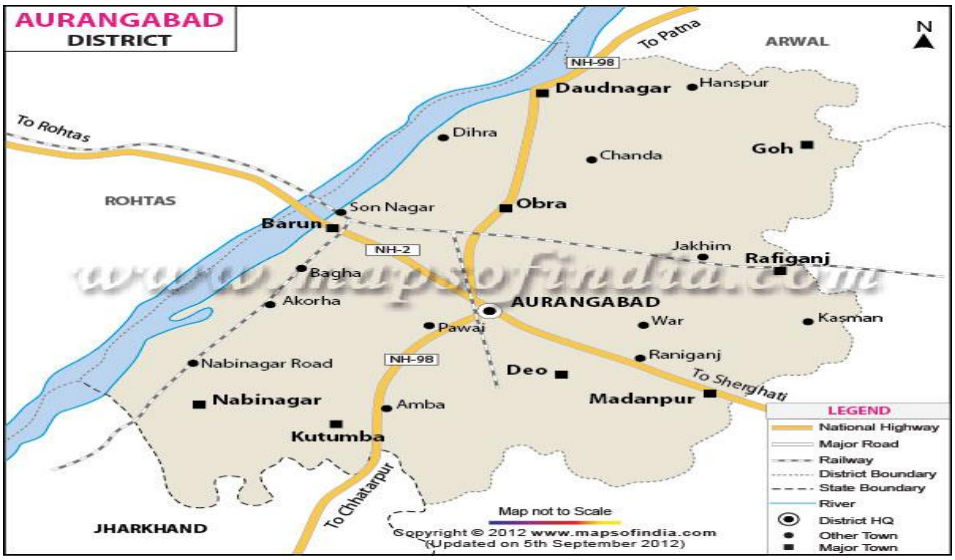

Figure 1: Study area

Rani-Pond has a natural boundary and is 300' long, 200' wide, and 20' deep. There is also a legend that once a bull cart full of people was crossing this pond when the cart suddenly fell in and all the people died. This pond has been considered defunded since that time, and it is no longer used for religious purposes or even bathing. Throughout the year, it receives domestic waste, agricultural runoff, and drainage water.
Surajkund, on the other hand, is 300' long, 300' wide, and 28' deep with a built boundary. Surajkund's temple is unique in that it faces west, towards the setting sun. According to legend, Lord Vishwakarma once built the temple in one night. One of the most anticipated holy days in North and Eastern India is Chhatha Puja. Devotees offer prayers to both the setting and rising Suns during this Puja. Before the festival, its water is cleaned twice a year.

Sampling of water

From March 2023 to June 2023, water samples were collected in triplicate fortnightly from Rani-Pond and Surajkund in Aurangabad during the morning hours. The samples were analysed in the laboratory for 11 physicochemical parameters, namely temperature, pH, electrical conductivity, turbidity, and dissolved water, and other parameters such as total dissolved solids, total alkalinity, total hardness, chloride, nitrate, and biological oxygen demand were monitored at the sampling site (Table 1).[16] Tables 2–3 show the observed values of the water parameters studied in Rani-Pond and Surajkund.

Statistical analysis

Graph Pad Prism 5 software was used to analyse the observed data for correlation analysis and the two-way t-test. $p<0.05$ was chosen as the significance level.

Overall Index of Pollution

An Overall Index of Pollution was developed to rank surface water quality based on pH, electrical conductivity, dissolved oxygen, biological oxygen demand, hardness, total dissolved solids, nitrate, chloride, and turbidity.[2] The classification of the Overall Index of Pollution for various categories was based on standard concentration ranges of these parameters (Table 7).[17]
The Overall Pollution Index is simple to calculate and adaptable to the addition or deletion of parameters. However, comparative assessments of water quality at completely different locations or times can be made only when the parameters included in the Overall Index of Pollution are the same, and recommendations for specific water uses can be made as a result.

Water quality index

The water quality index was calculated using the weighted arithmetic water quality index method, which involves multiplying water parameters by a weighting factor and then aggregating the results using a simple arithmetic mean.[3]
The Unit weight (W_i) of the ith parameter was an inversely proportional value to the recommended standard value of S_i

$$\text{(i)}\ W_i = \frac{K}{S_i}$$

The constant (K) for the quotient was calculated using the following equation:

$$\text{(ii)}\ K = \frac{1}{\left(\sum \frac{1}{S_i}\right)}$$

The total water quality index (WQI) was calculated by adding the quality rating to the unit weight.

$$\text{(iii)}\ WQI = \frac{\sum Q_i W_i}{\sum W_i}$$

$$Q_i = \left(\frac{M_i - I_i}{S_i - I_i}\right) \times 100$$

Where, Q_i = water quality rating of the ith parameter, i = the number of parameters included, M_i = the observed value of the ith parameter, I_i = the ideal value of the ith parameter, S_i = the standard permissible value of the ith parameter and K = constant for proportionality. In this experiment, the value of K was taken to be 1.234589.
The Ii for pH = 7, dissolved oxygen = 14.6 mg/l while for other parameters; it is equal to zero.[18]
W_i was calculated as a value reciprocally proportional to the standard.[17] The analyzed data were used to evaluate the relationship between different parameters and organized in Tables5-6.Based on the calculated WQI, the category of water quality types is shown in Table 4.[19]

RESULTS AND DISCUSSION

Assessment of variation of physicochemical parameters

Water quality is defined by various physicochemical parameters, which vary greatly due to a variety of factors such as source, location, type of pollution, seasonal fluctuations, and nearby human intervention, which is responsible for the enrichment of contaminants in the environment.

The current study sheds light on the water quality of Rani-Pond and Surajkund (Tables 2 and 3).

The water temperature, electrical conductivity, dissolved oxygen, total hardness, BOD, TDS, nitrate, and chloride levels of these two ponds differed significantly ($p<0.05$, $p<0.1$, or $p<0.001$) (Table 4). The dissolved oxygen, total alkalinity, electrical conductivity, and turbidity levels in these two bodies of water exceeded permissible limits.[17]

In the summer, the average water temperature of these bodies of water was 29.8-30.48^{0}C, with the lowest at 26.24±1.60^{0}C and the highest at 34.81±1.88^{0}C at Surajkund.
Temperature variations occur on a daily and fortnight basis as a result of various activities that can contribute to environmental changes caused by changes in the temperature of both surface water and groundwater. Water temperature increases are inversely proportional to pH and dissolved oxygen, but directly proportional to turbidity, conductivity, hardness, biochemical oxygen demand, total dissolved solids, and nitrate.[20]

During the summer season, the pH of the water was lowest (7.06±0.24) at Rani-Pond and highest (8.35±0.31) at Surajkund. The electrical conductivity and total dissolved solids are affected by pH changes. A pH range of 6.50-8.00 was previously reported for Samastipur's Karbala and Kali ponds.[20] Its concentration in six ponds in Patna ranging from 7.69 to 8.30 mg/l.[21] In a pond in Kerala, the pH fluctuated from 4.67 to 7.91.[20] A pH value of less than 6.5 causes the human body to stop producing vitamins, while a pH of more than 8.5 causes eye irritation and skin disorders.[22]These findings indicate that water is almost neutral to sub-alkaline and soft. The alkaline nature of water during the summer season could be attributed to lower levels of free carbon dioxide.[10,22]

The electrical conductivity of water is affected by ion concentration, nutrient status, and dissolved solids variation. During the summer, electrical conductivity ranged from 490.0 to 1149.0 µmho/cm. The presence of a high amount of dissolved inorganic substances in their ionised form is indicated by higher electrical conductivity. Kanth et al.[21]measured its value from 598 to 1217 µmho/cm in six ponds in Patna. Recently, electrical conductivity ranging from 740 to 1930 µmho/cm was reported in Kadapa, India.[19]However, two ponds of Samastipur had a lower electrical conductivity range of 360.0-405.0 µmho/cm.[10]

Dissolved oxygen of water with a range of 5.30-9.91 mg/l obtained during this study is desirable for good fauna and flora growth. Concentration of dissolved oxygen in six ponds ranging from 3.8 to 6.3 mg/l in Patna.[21] The dissolved oxygen level of 5.30 mg/l in Rani-Pond water during the summer months was possibly due to the lower oxygen-holding capacity of water at high temperatures and an increase in the microorganism's assimilation of biodegradable organic matter. The decomposition of organic matter began at low levels of dissolved oxygen in water.[23]

Domestic waste and local areas of human settlement in and around the lake contribute to the presence of biochemical oxygen demand in the water sample. Rani-Pond and Surajkund have biological oxygen demands ranging from 3.95±0.51 to 4.13±0.56 mg/l. Pre-summer saw the lowest value of 3.49 and summer saw the highest value of 4.69. It agreed with an earlier observation.[24] However, a higher range of biochemical oxygen demand was calculated at two ponds in India, ranging from 27.0-34.0 mg/l.[10]

Table 1. Measurement methods for the water quality parameters.

Sl. No.	Parameters	Unit	Method	Site of measurement	Sl. No.	Parameters	Unit	Method	Site of measurement
1.	Water temperature	^{0}C	Thermometric method	*in situ*	2.	pH	-	Portable pH meter	*in situ*
3.	Total dissolved solid	,,	Temperature controlled oven	In the Laboratory	4.	Dissolve oxygen	mg/ L	Winkler's volumetric method	,,
5.	Nitrate	,,	Cadmium reduction method	,,	6.	Total alkalinity	,,	Titration method	In the Laboratory
7.	Turbidity	NTU	Nephelometric method	,,	8.	Hardness	,,	EDTA method	,,
9.	Electric Conductivity	µmho/ cm	Conductivity meter	,,	10.	Chloride	,,	Silver nitrate method	,,

Table 2. Certain Physico-Chemical parameters of water of Rani Pond at Deo at Aurangabad during Summer Season 2023.

Months	Water Temp. (^{0}C)	pH	Conductivity (µmho/cm)	Turbidity (NTU)	DO (mg/L)	BOD (mg/L)	TA (mg/L)	Hardness (mg/L)	TDS (mg/L)	Chloride (mg/L)	Nitrate (mg/L)
March	27.5±3.05	7.44±0.08	876.0±26.02	18.5±7.02	9.80±0.26	3.58±0.74	207.5±4.26	135.4±8.84	482.3±20.1	10.45±0.98	11.10±0.17
April	28.0±4.24	7.70±0.24	1049.0±30.4	24.5±6.32	6.50±0.22	3.87±0.86	248.3±8.20	146.4±9.87	515.6±18.8	11.38±1.38	11.23±0.18
May	32.0±3.18	7.10±0.16	1097.0±18.16	24.0±5.44	6.20±0.30	4.52±0.66	260.4±6.42	192.6±8.48	607.9±13.1	14.42±1.32	11.42±0.56
June	34.4±3.44	7.06±0.24	1149.0±20.28	40.0±6.58	5.30±0.40	4.64±0.69	238.5±7.82	212.8±4.64	645.2±14.4	13.73±1.24	11.86±0.15
Mean	30.48±3.30	7.38±0.32	1042.75±118.43	26.75±9.24	6.95±1.97	4.13±0.56	238.68±22.63	171.73±36.78	562.75±76.44	12.50±1.88	11.41±0.33

Table 3. Physico-Chemical parameters of water of Surajkund at Deo of Aurangabad during Summer Season 2023.

Months	Water Temp. (^{0}C)	pH	Conductivity (µmho/cm)	Turbidity (NTU)	DO (mg/L)	BOD (mg/L)	TA (mg/L)	Hardness (mg/L)	TDS (mg/L)	Chloride (mg/L)	Nitrate (mg/L)
March	26.24±1.60	8.35±0.31	490.86±27.74	12.6±5.20	9.91±1.02	3.49±0.84	122.4±5.48	63.7±4.68	121.8±5.62	11.6±0.29	1.02±0.06
April	28.84±2.21	8.10±0.18	512.82±25.52	22.9±5.18	7.38±0.88	3.64±1.60	128.6±6.56	72.4±5.15	133.6±3.87	10.8±1.12	1.09±0.12
May	31.43±2.60	8.00±0.21	548.59±14.70	26.5±9.63	6.72±0.63	4.12±0.83	109.8±4.42	109.3±5.88	155.8±6.29	14.2±1.44	1.28±0.48
June	34.81±1.88	7.62±0.22	578.62±18.69	26.5±7.68	5.88±0.61	4.69±0.85	115.6±4.48	112.8±2.64	161.7±3.32	14.7±1.67	1.44±0.56
Mean	29.8±3.55	8.0±0.29	534.15±37.83	23.5±4.34	7.43±1.76	3.95±0.51	119.1±8.16	89.55±25.12	143.23±18.72	12.83±1.92	1.203±0.19

Table 4. Comparison of values of different physico-chemical parameters of water of Rani Pond and Surajkund (Tabulated r at df: 3 = 0.878 at 5%, 959 at 1% and 991 at 0.1% level and tabulated t at df: 6 and 2.45 at 5%, 3.71 at 1% and 5.96 at 0.1% level).

Parameters	Rani Pond V/S Surajkund				Parameters	Rani Pond V/S Surajkund			
	Calculated r value	Level of significance	Calculated t value	Level of significance		Calculated r value	Level of significance	Calculated t value	Level of significance
WT (^{0}C)	0.984	p<0.01**	7.765	P<0.001***	pH	0.743	$p>0.05^{NS}$	1.568	$p>0.05^{NS}$
Cond. (µmho/cm)	0.905	P<0.05*	3.004	p<0.05*	DO (mg/L)	0.994	p<0.001***	13.12	P<0.001***
BOD(mg/L)	0.927	P<0.05*	3.486	P<0.05*	TA (mg/L)	0.384	$p>0.05^{NS}$	0.901	$p>0.05^{NS}$
HA (mg/L)	0.994	p<0.001***	8.42	p<0.001***	TDS (mg/L)	0.994	p<0.001***	13.22	p<0.001***
Chloride (mg/L)	0.898	P<0.05*	2.88	P<0.05*	Nitrate (mg/L)	0.975	p<0.01**	6.26	p<0.001***
Turbidity (NTU)	0.748	$p>0.05^{NS}$	1.594	$P>0.05^{NS}$					

(*=Significant, **=Moderately Significant, ***= Highly Significant)

Table 5. Calculation of Overall Index of Pollution (OIP) and Water Quality Index of Rani Pond, Deo at Aurangabad, Bihar, India (A=March, B=April, C=May and D= Jume) (K = 1.234598)..

Sl. No.	Parameters	Season	Standard Value (Si)	Ideal value (Ii)	Observed values (Mi)		Sub index (Qi)		OIP Score		Unit weight (Wi)=K/Si	Wi x Qi	
					Monthly	Seasonal	Monthly	Seasonal	Monthly	Seasonal		Monthly	Seasonal
1.	pH	A	7.5	7.0	7.6	7.37	120.0	74.0	2	1	0.1646	19.75	12.18
		B	7.5	7.0	7.7	7.37	140.0	74.0	2	1	0.1646	23.07	12.18
		C	7.5	7.0	7.1	7.37	20.0	74.0	1	1	0.1646	3.29	12.18
		D	7.5	7.0	7.1	7.37	20.0	74.0	1	1	0.1646	3.92	12.18
2.	DO ($mg.L^{-1}$)	A	5	14.6	9.8	6.95	50.00	79.69	4	4	0.2469	12.34	19.68
		B	5	14.6	6.5	6.95	84.37	79.69	4	4	0.2469	20.83	19.68
		C	5	14.6	6.2	6.95	87.50	79.69	8	4	0.2469	21.60	19.68
		D	5	14.6	5.3	6.95	96.87	79.69	8	4	0.2469	23.92	19.68
3.	TA ($mg.L^{-1}$)	A	200	0	207.5	238.67	103.75	119.33	4	4	0.0062	0.6432	0.7398
		B	200	0	248.3	238.67	124.15	119.33	4	4	0.0062	0.7697	0.7398
		C	200	0	260.4	238.67	130.20	119.33	4	4	0.0062	0.8072	0.7398
		D	200	0	238.5	238.67	119.25	119.33	4	4	0.0062	0.7393	0.7398
4.	HA ($mg.L^{-1}$)	A	200	0	135.4	171.73	67.70	85.86	2	4	0.0062	0.4197	0.5323
		B	200	0	146.4	171.73	73.20	85.86	2	4	0.0062	0.4538	0.5323
		C	200	0	192.6	171.73	96.30	85.86	4	4	0.0062	0.5971	0.5323
		D	200	0	212.5	171.73	106.25	85.86	4	4	0.0062	0.6588	0.5323
5.	TDS ($mg.L^{-1}$)	A	500	0	482.3	562.75	96.46	112.55	1	2	0.0025	0.2411	0.2814
		B	500	0	515.6	562.75	103.12	112.55	2	2	0.0025	0.2578	0.2814
		C	500	0	607.9	562.75	121.58	112.55	2	2	0.0025	0.3039	0.2814
		D	500	0	645.2	562.75	129.04	112.55	2	2	0.0025	0.3226	0.2814
6.	Cl^- ($mg.L^{-1}$)	A	250	0	10.45	12.49	4.18	5.00	1	1	0.0049	0.0205	0.0245
		B	250	0	11.38	12.49	4.55	5.00	1	1	0.0049	0.0222	0.0245
		C	250	0	14.42	12.49	5.77	5.00	1	1	0.0049	0.0281	0.0245
		D	250	0	13.73	12.49	5.49	5.00	1	1	0.0049	0.0269	0.0245
7.	NO_3^- ($mg.L^{-1}$)	A	45	0	11.10	11.40	24.67	25.33	1	1	0.0247	0.6093	0.6257
		B	45	0	11.23	11.40	24.96	25.33	1	1	0.0247	0.6164	0.6257
		C	45	0	11.42	11.40	25.38	25.33	1	1	0.0247	0.6268	0.6257
		D	45	0	11.86	11.40	26.35	25.33	1	1	0.0247	0.6510	0.6257
8.	BOD ($mg.L^{-1}$)	A	5.0	0	3.50	4.13	70.0	82.6	4	4	0.4115	28.81	33.99
		B	5.0	0	3.80	4.13	76.0	82.6	4	4	0.4115	31.27	33.99
		C	5.0	0	4.57	4.13	91.4	82.6	4	4	0.4115	37.61	33.99
		D	5.0	0	4.64	4.13	92.8	82.6	4	4	0.4115	38.19	33.99
9.	Turbidity (NTU)	A	5.0	0	18.5	26.75	370.0	535.0	4	4	0.4115	152.25	220.15
		B	5.0	0	24.5	26.75	490.0	535.0	4	4	0.4115	201.64	220.15
		C	5.0	0	24.0	26.75	480.0	535.0	4	4	0.4115	197.52	220.15
		D	5.0	0	40.0	26.75	800.0	535.0	4	4	0.4115	329.20	220.15
10.	EC	A	500	0	876.0	1042.75	175.8	208.55	4	8	0.0025	0.4395	0.5214
		B	500	0	1049.0	1042.75	209.8	208.55	8	8	0.0025	0.5245	0.5214
		C	500	0	1097.0	1042.75	219.4	208.55	8	8	0.0025	0.5485	0.5214
		D	500	0	1149.0	1042.75	229.8	208.55	8	8	0.0025	0.5745	0.5214

		A						Mean	2.7	3.3		215.52	288.73
		B						OIP	3.2	3.3	ΣWQI	279.45	288.73
		C						Score	3.7	3.3		262.93	288.73
		D							3.7	3.3		398.20	288.73
Annual average of Overall Index of Pollution (OIP) and water quality index (WQI) of Rani Pond, Deo at Aurangabad, Bihar, India									3.35	3.3		289.03	288.73

Table 6. Calculation of Overall Index of Pollution (OIP) and Water Quality Index of Surajund, Deo at Aurangabad, Bihar, India (A=March, B=April, C=May and D= Jume) (K = 1.234598).

Sl. No.	Parameters	Season	Standard Value (Si)	Ideal value (Ii)	Observed values (Mi)		Sub index (Qi)		OIP Score		Unit weight (Wi)=K/Si	Wi x Qi	
					Monthly	Seasonal	Monthly	Seasonal	Monthly	Seasonal		Monthly	Seasonal
1.	pH	A	7.5	7.0	8.3	8.0	260	200	4	2	0.1646	42.80	32.92
		B	7.5	7.0	8.1	8.0	220	200	4	2	0.1646	36.21	32.92
		C	7.5	7.0	8.0	8.0	200	200	2	2	0.1646	32.92	32.92
		D	7.5	7.0	7.6	8.0	120	200	2	2	0.1646	19.76	32.92
2.	DO ($mg.L^{-1}$)	A	5	14.6	9.91	7.43	48.85	74.69	1	4	0.2469	12.06	18.44
		B	5	14.6	7.30	7.43	76.04	74.69	4	4	0.2469	18.77	18.44
		C	5	14.6	6.70	7.43	82.29	74.69	4	4	0.2469	20.32	18.44
		D	5	14.6	5.80	7.43	91.67	74.69	8	4	0.2469	22.63	18.44
3.	TA ($mg.L^{-1}$)	A	200	0	122.4	119.1	61.20	59.55	2	2	0.0062	0.3794	0.3692
		B	200	0	128.6	119.1	64.30	59.55	2	2	0.0062	0.3987	0.3692
		C	200	0	109.8	119.1	54.90	59.55	2	2	0.0062	0.3404	0.3692
		D	200	0	115.6	119.1	57.80	59.55	2	2	0.0062	0.3584	0.3692
4.	HA ($mg.L^{-1}$)	A	200	0	63.7	89.55	31.85	44.78	1	2	0.0062	0.1975	0.2776
		B	200	0	72.4	89.55	36.20	44.78	1	2	0.0062	0.2244	0.2776
		C	200	0	109.3	89.55	54.65	44.78	2	2	0.0062	0.3388	0.2776
		D	200	0	112.8	89.55	56.40	44.78	2	2	0.0062	0.3497	0.2776
5.	TDS ($mg.L^{-1}$)	A	500	0	121.8	143.2	24.36	28.64	1	1	0.0025	0.0609	0.0716
		B	500	0	133.6	143.2	26.72	28.64	1	1	0.0025	0.0668	0.0716
		C	500	0	155.8	143.2	31.16	28.64	1	1	0.0025	0.0779	0.0716
		D	500	0	161.7	143.2	38.34	28.64	1	1	0.0025	0.0958	0.0716
6.	Cl^- ($mg.L^{-1}$)	A	250	0	11.6	12.83	4.46	5.13	1	1	0.0049	0.0219	0.0252
		B	250	0	10.8	12.83	4.32	5.13	1	1	0.0049	0.0212	0.0252
		C	250	0	14.2	12.83	5.68	5.13	1	1	0.0049	0.0278	0.0252
		D	250	0	14.7	12.83	5.88	5.13	1	1	0.0049	0.0288	0.0252
7.	NO_3^- ($mg.L^{-1}$)	A	45	0	1.02	1.203	2.27	2.67	1	1	0.0247	0.0561	0.0659
		B	45	0	1.09	1.203	2.42	2.67	1	1	0.0247	0.0598	0.0659
		C	45	0	1.26	1.203	2.80	2.67	1	1	0.0247	0.0692	0.0659
		D	45	0	1.44	1.203	3.20	2.67	1	1	0.0247	0.0790	0.0659
8.	BOD ($mg.L^{-1}$)	A	5.0	0	3.5	3.95	70.0	79.0	4	4	0.4115	28.81	32.51
		B	5.0	0	3.6	3.95	72.0	79.0	4	4	0.4115	29.63	32.51
		C	5.0	0	4.1	3.95	82.0	79.0	4	4	0.4115	33.74	32.51
		D	5.0	0	4.6	3.95	92.0	79.0	4	4	0.4115	37.86	32.51
9.	Turbidity (NTU)	A	5.0	0	12.6	23.5	252.0	470.0	4	4	0.4115	103.70	193.41
		B	5.0	0	22.9	23.5	458.0	470.0	4	4	0.4115	188.47	193.41
		C	5.0	0	26.5	23.5	530.0	470.0	4	4	0.4115	218.09	193.41
		D	5.0	0	26.5	23.5	530.0	470.0	4	4	0.4115	218.09	193.41
10.	EC	A	500	0	490.0	534.15	98.0	106.83	1	2	0.0025	0.2450	0.2671
		B	500	0	518.0	534.15	103.6	106.83	2	2	0.0025	0.2590	0.2671
		C	500	0	552.8	534.15	110.56	106.83	2	2	0.0025	0.2764	0.2671
		D	500	0	575.8	534.15	115.16	106.83	2	2	0.0025	0.2879	0.2671
		A						Mean	1.9	2.3		188.33	278.36
		B						OIP	2.4	2.3	ΣWQI	274.11	278.36
		C						Score	2.3	2.3		306.20	278.36
		D							2.7	2.3		299.54	278.36
Annual average of Overall Index of Pollution (OIP) and water quality index (WQI) of Rani Pond, Deo at Aurangabad, Bihar, India									2.325	2.3		267.05	278.36

Table 7. Overall Index of Pollution (OIP) of water (Sargoankar and Deshpande, 2003; modified after BIS, 2012:IS-10500).

Category	OIP Index	Class	pH	E. Cond. ($\mu mho.cm^{-1}$)	DO ($mg.L^{-1}$)	BOD ($mg.L^{-1}$)		HA ($mg.L^{-1}$)	TA ($mg.L^{-1}$)	TDS ($mg.L^{-1}$)	Cl^- ($mg.L^{-1}$)	Nitrate ($mg.L^{-1}$)	Turbidity (NTU)
Excellent	0-1	C1	6.5–7.5	500	9.5-10.5	1.5		75	75	500	150	20	5
Good (Acceptable)	1-2	C2	6.0–6.5 and 7.5–8.0	750	8.5-11.5	3		150	150	1500	250	45	10
Slightly polluted	2-4	C3	5.0–6.0 and 8.0–9.0	1000	6.5-12.5	6		300	300	2100	600	50	100
Polluted	4-8	C4	4.5–5.0 and 9.0–9.5	2000	3.0-15.5	12		500	500	3000	800	100	250
Heavily polluted	8-16	C5	<4.5 and >9.5	>2000	<3.0 and >15.5	24		>500	>500	>3000	>800	200	>250

Table 8. Water Quality Scale.

Sl. No.	Water Category	Mohanty (2004)	Ramakrishnaiah (2009)	Yadav et al, (2010)	Sl. No.	Water Category	Mohanty (2004)	Ramakrishnaiah (2009)	Yadav et al,(2010)
1.	Excellent	<50	<50	0-25	2.	Good	50-100	50-100	26-50
3.	Poor	100-200	100-200	51-75	4.	Very poor	200-300	200-300	76-100
5.	Unsuitable	>300	>300	>100					

The total alkalinity ranged between 109.8 and 260.4mg/l. Summertime total alkalinity of 238.68±22.63 mg/l Rani-Pond water may be due to increased photosynthesis and increased carbon dioxide use.[17, 25]Its concentration in six ponds ranging from 204 to 408 mg/l in Patna.[21] In Andhra Pradesh, a total alkalinity range of 38-210mg/l was recently calculated.[19] The highest total alkalinity of water during the summer had previously been reported.[26]The presence of highly alkaline wastewater and sewage is indicated by high alkalinity. The degradation of plants, living organisms, and organic waste is also responsible for an increase in carbonate and bicarbonate levels, which raises alkalinity.

Water hardness is defined as its ability to react with detergent. It refers to the effects of dissolved minerals on the suitability of water for domestic, industrial, and drinking purposes.[27] During the summer, the hardness values of Rani-Pond ranged from 135.4-212.5 and 63.7-112.8 mg/l of Surajkund. However, a hardness range of 165.0-180.0 mg/l was calculated for two ponds of Samastipur.[10] Kanth et al.[21] measured its concentration in six ponds in Patna ranging from 148 to 384 mg/l. High hardness values are most likely due to the regular addition of large quantities of detergents used by nearby residential areas that drain into water bodies. Water hardness is defined as its ability to react with detergent. It refers to the effects of dissolved minerals (size < 0.0002cm or 2μ) on the suitability of water for domestic, industrial, and drinking purposes.[27] During the summer, the hardness values of Rani-Pond ranged from 135.4-212.5 and 63.7-112.8 mg/l of Surajkund. However, at Samastipur, a hardness range of 165.0-180.0 mg/l was calculated for two ponds.[10] Kanth et al.[21] measured its concentration ranging from 148 to 384 mg/l in six ponds in Patna. High hardness values are most likely due to the regular addition of large quantities of detergents used by nearby residential areas that drain into water bodies.

Electrical conductivity is generally thought to be proportional to total dissolved solids. However, there are numerous standards governing total dissolved solids and electrical conductivity in water. The difference between these two parameters is due to a conversion factor of 0.50 to 1.1 from electrical conductivity to total dissolved solids.

If the pH = 7 and the dissolved oxygen level = 14.6 mg/l, the amount of solid dissolved solids is zero.[18]

While total dissolved solids measurements are derived from conductivity, some states, regions, and agencies frequently set total dissolved solids maximum for water quality rather than a conductivity limit.[4]

During the summer, chloride levels ranged from 10.45 to 14.70 mg/l. Surajkund had the highest chloride concentration of 14.70. At Patna, concentration of chloride in six ponds ranging from 40 to 100 mg/l.[21] However, earlier research discovered a chloride range of 155.0-180.0 mg/l for two ponds of Samastipur.[10] Chloride levels in water decreased from summer to winter, as previously observed.[28] Excess chloride in water reduces the dissolved oxygen content, which is harmful to aquatic organisms.[27]

Nitrate is an important nutrient that influences the productivity of the aquatic ecosystem. During the summer, the nitrate levels in Rani-Pond and Surajkund water ranged from 1.02 to 11.86 mg/l. However, a high nitrate range of 42.0-51.0 mg/l was found in two ponds of Samastipur. [10] Summertime nitrate levels are high due to the excessive entry of water from agricultural fields, decayed vegetables, animal matter, and other sources.[29]

Turbidity is the amount of water that has lost its purity due to the presence of balanced colloidal particles. Turbidity is measured concerning a siliceous material suspension, silica. The standard unit of turbidity is the amount of turbidity caused by one division of Fuller's earth in a million parts of distilled water. During the summer, the turbidity of the water in these bodies was 12.6-40.0 mg/l. The summer season of pond water has the highest turbidity. High turbidity is caused by suspended solids in water, such as slits, clays, and industrial waste sewage. Turbidity is caused by the presence of suspended particulate matter in water. These particles absorb light and raise the temperature of the water's surface, resulting in low dissolved oxygen levels.

Calculation of Overall Index of Pollution

The overall pollution index was calculated using the physicochemical parameters of these ponds. It is easy to estimate and adaptable to changes in physicochemical parameters. To calculate the overall pollution index, the standards were followed (Table 7).[2] The overall pollution index of Rani-Pond and Surajkund was found to be 3.3 and 2.3, with a range of 2.7-3.7 and 1.9—2.7, respectively (Tables 5-6). The average value indicates that the water in Rani-Pond and

Surajkund is classified as Class C4 (2 < OIP < 3.9), or slightly polluted. A recent study found that the water quality of the Ganga River was acceptable in summer C4 (2 < OIP < 3.9) in Haridwar, India.[30]

Water pollution index (WPI) suggested four categories of water quality: WPI < 0.5 denotes the excellent quality, 0.5 > WPI < 0.75 denotes the good quality, 0.75 > WPI < 1 denotes moderately polluted water, and WPI > 1 denotes highly polluted water.[31] According to this scale, the water in Rani-Pond and Surajkund is highly polluted

Calculation of water quality index

The water quality index[32-34] was ascertained utilizing the weighted arithmetic index equations specified previously, and the values obtained are presented in Tables 5-6 showing the monitored values (M_i) of the selected eleven/ten water quality parameters, standard drinking water values (S_i)[17], unit weight (W_i), sub-index water quality rating (Q_i) and $W_i\ Q_i$

I. Water quality index with turbidity

The average water quality index of Rani-Pond was 215.52-398.20, indicating it was in the very poor (D) to unsuitable water category (E), whereas Sundarkund was in the poor category (C) to unsuitable water category (E) (Table 8). The water quality index of Hebal Lake, Bangalore, India, was recently calculated for its good (B) to poor (C) category.[35] Furthermore, a water quality index range of 33.65-125.73 was discovered at Obulavaripalli in Kadapa, India, indicating the excellent (A) to poor (C) category.[19]

II. Water quality index without turbidity.

Rani-Pond's average water quality index of 63.27-69.0 indicated it was in the good (B) water category, while Sundarkund's average water quality index of 84.63-88.11 indicated the same (Table 8).

As a result, it appears that turbidity is important in calculating the water quality index. However, it was discovered that turbidity has the least impact on the calculation of the overall pollution index.

The analysis reveals that the water in these ponds is suitable for domestic and irrigation purposes but not for drinking. Previous observations confirm the same trend and closer values of physicochemical parameters as observed in this work.[10,21] However, it requires some sort of treatment before consumption, as well as protection from contamination.

CONCLUSION

Seasonal variations in various physicochemical parameters of Rani-Pond and Surajkund were investigated to calculate the overall pollution index, water quality index, and water pollution index. Water quality analysis was used to investigate variations in the water quality index values. The values of the Overall Index of Pollution indicate that the water in these ponds falls into Category C4. The overall water quality index was in the very poor (Category D) range. Based on the findings of this study, it is possible to conclude that effective measures are required to prevent the entry of contaminated water and to improve the overall water quality of these bodies of water.

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