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USE OF OVERALL INDEX OF POLLUTION AND WATER QUALITY INDEX TO ASSESS RANI POND AT AURANGABAD, BIHAR, INDIA

Sunita K Sharma[1], Vikash K Ravi[2], Sandeep Kumar[3] and Dina N Pandit[3]*
[1]PG Department of Zoology, Maharaja College, Arrah-802 301
[2]Department of Botany, Sri Shankar College, Sasaram-821 115
[3]Department of Zoology, Veer Kunwar Singh University, Arrah-802 301
Corresponding author email: panditdina@gmail.com

ABSTRACT

The present work was carried out to apply overall index of pollution and water quality index to assess status of Rani Pond, Aurangabad, Bihar, India which has been under pressure due to the increasing anthropogenic activities. Physicochemical parameters like water temperature, pH, electrical conductivity, dissolved oxygen, total alkalinity, hardness, total dissolved solids, biochemical oxygen demand chloride, fluoride and nitrate were analyzed using standard procedures. The values obtained were compared with the guidelines for drinking purpose suggested by BIS (2012). The result shows the higher concentration of electrical conductivity, hardness, total dissolved solids and fluoride beyond the permissible limit. Ten parameters were selected to derive the overall index of pollution and water quality index for the estimation of water potential. The range of 2.70-3.50 of overall index of pollution and 165.83-224.58 of water quality index indicating that the water of Rani Pond is not fit for drinking including both human and animals. The implementation of overall index of pollution and water quality index is necessary for proper management of the Rani Pond and it will be a very helpful tool for the public and decision makers to evaluate the water quality of the Rani Pond for sustainable management.

Keywords: Water quality, physicochemical parameters, overall index of pollution, water quality index, Rani Pond, India.

Introduction

Surface water bodies have been the basic resource to fulfill all kinds of human requirements but unfortunately today water quality of these water resources is under severe environmental stress and under threat due to various types of anthropogenic activities and the condition is more pathetic in lentic water bodies. The Overall Index of Pollution was developed by Sargaonkar and Deshpande (2003) for surface water quality assessment. For taking a better picture of water quality the data of various qualities indicating parameters data could be aggregated into an overall index called water quality index (Horton, 1965).

Water quality index is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers. It may be defined as "a mathematical instrument used to transform large quantities of water quality data into a single number, which provides a simple and understandable tool for managers and decision makers on the quality and possible uses of a given water body" (Kannel *et al.,* 2017).

Many researchers have carried out studies on water quality assessment using Water quality index around the world including India in various water bodies (Shardendu and Ambasht, 1988; Abdul *et al.,* 2010; Umamaheshwari, 2010; Sinha *et al.,* 2014). However, there was no literature which reveals scientific study carried out with respect to Overall Index of Pollution and Water quality index from Aurangabad, Bihar, India, currently considered as a part of red corridor.

The rationale of the present study was to identify the water quality status of the Rani Pond of Deo, Aurangabad using Overall Index of Pollution and Water quality index. This study will also help in assessment and periodic monitoring of water quality for proper management strategies to minimize the water pollution level in spite of increasing anthropogenic activity and urbanization within the sensitive area.

Material and Methods

Study area

Aurangabad, Bihar, India lies between $24^0$30'-$25^0$15'N and $84^0$00'-$84^0$45'E. During the summer days temperature rises up to 40^0C to 50^0C, whereas during the winter temperature falls almost near 5^0C. Rain fall in this region is average near 50cm to 75 cm. DEO is a place of historical importance, located 18-km to the southeast Aurangabad and lies between $24^0$25'N and $84^0$40'E. Rani Pond is one of the places of historical importance at Deo, Aurangabad. Rani Pond is perennial and 300feet long, 200feet wide and 20feet deep with an almost damaged bank all around. It practically receives domestic wastes and drainage water throughout the year.

Sampling of water

The water samples were collected in triplicate fortnightly from Rani Pond, Deo, Aurangabad between 2017-2019 during morning hours. The samples analysed in the laboratory for 11 physico-chemical parameters namely temperature, pH, electrical conductivity and dissolved water were monitored at the sampling site and other parameters like total dissolved solids, total alkalinity, total hardness, total suspended solid, chloride, nitrate, fluoride and biological oxygen demand were analysed in the laboratory as per the standard procedures of APHA (2012).

Overall Index of Pollution

Sargaonkar and Deshpande (2003) have developed Overall Index of Pollution for Surface water quality based on pH, electrical conductance, dissolved oxygen, BOD, hardness, total dissolved solids, nitrate, chloride, and fluoride. The Overall Index of Pollution classification for different categories along with ranges of concentrations of these parameters according to BIS (2012) is given in Table (2).

Excellent water category means pristine. Acceptable needs only disinfection. Slightly Polluted requires filtration and disinfection. Polluted requires special treatment and disinfection. Heavily Polluted water cannot be used for any purpose. In case of Polluted and Heavily Polluted classes, more stringent measures for abatement of pollution are necessary to avoid any severe effects on human health, vegetation and aquatic life.

The Overall Index of Pollution is simple to estimate and flexible to the addition or deletion of parameters. However, comparative assessments of water quality at different places or at different times can be made only when the parameters included in the Overall Index of Pollution are the same, and accordingly recommendations may be made regarding the specific use of water.

Water quality index

The water quality index was determined using the weighted arithmetic water quality index method s proposed by Horton (1965) in which water parameters are multiplied by a weighting factor and are then aggregated using a simple arithmetic mean by these three equations:

The Unit weight (Wi) of the i^{th} parameter was an inverse proportional value to the recommended standard value of Si

(i) Wi = K/Si

Constant (K) for proportionality was calculated using following equation:

(ii) K = 1/ Σ (1/Si)

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

(iii) WQI = Σ QiWi/Σ Wi

Where, Qi = water quality rating of the i^{th} parameter, i = number of parameters included, Mi = the observed value of the i^{th} parameter, Li = the ideal value of the i^{th} parameter, Si = the standard permissible value of the i^{th} parameter and K = constant for proportionality. In this experiment, the value of K was taken to be 1.234589.

The Li for pH = 7, dissolved oxygen = 14.6 mg/l, and for other parameters, it is equal to zero (Chowdhury *et al.,* 2012).

The Wi was calculated as a value inversely proportional to the standard of the BIS (2012) (Si). The analyzed data were compared to the BIS (2012) recommended standards to evaluate the relationship between different parameters and arranged in table 3.

Based on the calculated WQI, the category of water quality types is shown in Table 4 (Prasad *et al.,* 2019).

Results and Discussion

(A) Assessment of physico-chemical parameters

The analysis of physico-chemical parameters provides a considerable insight of water quality of Rani Pond. This study identifies the parameters which are responsible for decreasing the water quality. The obtained physicochemical parameters' average values were compared with BIS (2012) for each sampling site in Rani Pond (Table 1).

The highest water temperature recorded during summer/pre-monsoon with 33.58±6.5^{0}C and a minimum of 7.68±5.7^{0}C recorded during winter in this pond. The higher temperature during the summer season can be attributed probably to high atmospheric temperature and low relative humidity (Sinha *et al.,* 2004; Pandit *et al.,* 2020). Another major factor for this variation of water parameters may be continuous discharge of household residuals/sewage effluents (Mamun *et al.,* 2020).

The pH of Rani Pond ranges from 6.35±0.12 in monsoon to 7.33±0.09 in winter months indicated that water is almost neutral to sub-alkaline. The high organic content will tend to decrease the pH due to its carbonate chemistry. The observation on pH is in close conformity with the findings of Ghosh (2018) from a pond of West Bengal, India.

The values of dissolved oxygen were found in the range of 4.62±0.48 during the monsoon to 6.79±0.44 mg.L^{-1} during the winter. The low dissolved oxygen suggests the poor quality of water indicating slow rate of photosynthesis by phytoplankton present in the Rani pond. The highest dissolved oxygen during winter as cold water can hold more dissolved oxygen than monsoon. The dissolved oxygen values also depend on many factors like temperature, microbial population, pressure and time of sampling. These results on dissolved oxygen were supported by the findings of Mahobe and Mishra (2013) of two ponds of Chhattisgarh, India.

Alkalinity of water is the capacity to neutralize strong acids and is primarily a function of carbonate, bicarbonate and hydroxide content, being formed due to the dissolution of carbon dioxide in water (Dallas and Day, 2004). During the present investigation, the maximum alkalinity of 277.1±7.15 mg.L^{-1} was registered against the minimum of 195.9±3.70 mg.L^{-1}. Ghosh (2018) also reported the highest total alkalinity during pre-monsoon and the lowest during winter in a pond of West Bengal as observed in our study. The lower alkalinity values in the present investigation may be attributed to the high flow discharge (Harlow, 2003).

The presence of biochemical oxygen demand in the water sample is from domestic waste and local areas of human settlement in and around the lake. Biological oxygen demand in Rani Pond ranges from 2.02±0.41 to

5.95±0.41mg.L^{-1}. The lowest value was recorded during post-monsoon and maximum during pre-monsoon months. It showed conformity with the observation of Chatterjee (1992).

The electrical conductance values of the study site range from 803.5±10.7 to 1204.2±10.7 μmho.cm^{-1}. The lowest values were observed during winter and highest during monsoon. The higher value of electrical conductance is attributed to the high degree of anthropogenic activities like waste disposal, household waste, and chemicals runoff from agricultural activities (Clenaghan *et al.,* 1998). All the recorded values of electrical conductance exceeded limit of BIS (2012). The high concentration of electrical conductance implies the high level of pollution of the Rani pond.

Total dissolve solid values of the study area range from 411.2±3.9 to 654.8±4.07 mg.L^{-1}. The high value of total dissolve solid was observed during pre-monsoon and lowest during winter. The total dissolve solid proportionality enhanced the electrical conductivity in the water. The total dissolved solids tend to be higher due to increased siltation caused by surface run-off (Shinde, 2011). The total dissolve solid originates from natural sources, sewage, urban and agricultural runoff. Most the recorded values of total dissolve solid exceeded limit of BIS (2012).

Total hardness values range from 133.2±4.85 to 265.1±4.75 mg.L^{-1} recorded minimum in winter and maximum at premonsoon. The hardness values during winter months were within the permissible limit (BIS 2012). Mishra *et al.* (2014) observed the pond water quality in Varanasi and found that the hardness values varied from 146 to 268 mg.L^{-1}.

Chloride occurs naturally in all types of water. It enters surface waters with the weathering of some sedimentary rocks, industrial and sewage effluents and agricultural and road run-off (Link and Inman, 2003). In the present study, the levels of chloride fluctuated between 10.41±0.54 to 16.98±0.51 mg.L^{-1}. Arya *et al.* (2011) recorded similar finding on chloride in Laxmi pond, Uttar Pradesh, India as observed in this work. The highest chloride concentrations may be explained on the account of the increasing anthropogenic activities (Mooers and Alexander, 1994).

Nitrate is known to be a vital nutrient for growth, reproduction, and the survival of organisms. In the present investigation, the concentration of nitrate could not show marked fluctuations and ranged from 11.15±0.19 to 12.54±0.29 mg.L^{-1}. As the pond received wastewater from neighboring households, it resulted in comparatively high nitrate values. However, high nitrate levels are not good for aquatic life (Kilham, 1990). Further, the fluctuations noticed in the concentration of nitrate may be attributed to increased agricultural runoff and sewage contamination (Ali *et al.,* 1999).

Fluorine occurs in varying concentrations in soil, water, plants and animals both naturally and anthropogenic activities. The presence of fluoride in water has become a worldwide problem. The BIS (2012) recommended 1.0 mg.L^{-1}fluoride as permissible limit for drinking water. Fluoride from 0.06 to 0.6 mg.L^{-1} along the Kolong River Nagaon, Assam was observed by Sharma *et al.* (2017). Its concentration of 1.5-4.0 mg.L^{-1} resulted in dental fluorosis (Annadurai *et al*., 2014). The mean values of fluoride ranged from 0.80±0.01 mg.L^{-1} during winter, 1.40±0.03 mg.L^{-1} during monsoon in this study and exceeded BIS (2012) standard.

(B) Calculation of Overall Index of Pollution

The standards given by Sargaonkar and Deshpande (2003) were followed to calculate overall index of pollution (Table 2). The average value of overall index of pollution of these water bodies was found to be 3.20 with the range of 2.70-3.50 (Table 3) taking the observed and standard values of physico-chemical parameters. The value indicates that the water of this pond comes under Class C3 (4 < OIP < 7.9) or slightly polluted category. The work showed parallelism with the findings of Sinha *et al.,* (2014) for the range of 3.3-3.7 (C3) of two ponds of Samastipur, Bihar. Recently, the water quality status of Ganga River at Haridwar to be C3 category with overall index of pollution of 2.18 was also calculated by Kamboj and Kamboj (2019).

(C) Calculation of Water Quality Index

The water quality index for the river bodies was ascertained utilizing the weighted arithmetic index equations specified previously, and the values obtained are presented in Table 3, which shows the monitored values (Mi) of the selected ten water quality parameters, standard drinking water values (Si) according to the BIS (2012), unit weight (Wi), sub-index water quality rating (Qi) and WiQi.

According to the classification of water quality in light of weighted arithmetic water quality index method, as given in Table 3, the average of water quality index of Rani Pond was 193.5 with a range of 165.85-224.58. These values show poor/very poor water quality, and this may be due to various natural phenomena and anthropogenic activities occurring along the pond (Table 4). These values are close to the findings of Sinha *et al.* (2014) for the range of 118.52-156.92 (Category C or poor water quality) of two ponds of Samastipur, Bihar. Recently, Sudarshan *et al.* (2019) calculated water quality index from 59.8-136.09 of Hebal Lake, Bangalore, India for its good to poor category.

The high value of water quality index has been found to be mainly from the higher values of fluoride and biochemical oxygen demand followed by dissolved oxygen and to some extent to pH in the water. This water quality rating study clearly shows that the status of the pond is eutrophic or hypereutrophic and is unsuitable for the human uses.

Conclusions

From the foregoing observations of the physico-chemical parameters, it can be concluded that the present pond show the characters of eutrophication. Low dissolved oxygen, high biochemical oxygen demand and high nitrate concentrations indicate the eutrophic status of the entire pond. The overall index of pollution from 2.70-3.50 and Water Quality Index from 165.85-224.58 indicate poor/very poor water quality index of Rani Pond. The present study is helpful in proper planning and management of available water resource for drinking purpose.

Table 1: Certain Physico-Chemical parameters of water of Rani Pond at Deo at Aurangabad during 2018-2019.

	Water Temp. (^{0}C)	pH	Electrical Conductivity (μmho.cm^{-1})	Dissolved Oxygen (mg.L^{-1})	Biochemical Oxygen Demand (mg.L^{-1})	Total Alkalinity (mg.L^{-1})	Hardness (mg.L^{-1})	Total Dissolved Solid (mg.L^{-1})	Chloride (mg.L^{-1})	Nitrate (mg.L^{-1})	Fluoride (mg.L^{-1})
JAN	7.68±5.7	7.25±0.07	803.5±10.7	6.83±0.39	2.02±0.41	196.0±4.26	135.6±3.54	411.2±3.9	10.41±0.54	11.18±0.17	0.82±0.01
FEB	13.47±4.6	7.18±0.08	885.6±24.1	6.79±0.44	2.10±0.35	212.9±3.42	133.2±4.85	625.0±3.6	10.69±0.49	11.19±0.12	0.84±0.03
MAR	18.38±6.4	7.05±0.06	904.5±20.9	5.95±0.38	3.11±0.18	249.1±5.07	160.7±3.53	621.6±4.9	12.72±0.80	11.17±0.14	0.88±0.02
APR	25.51±6.3	6.71±0.04	1003.1±019.4	5.89±0.44	4.08±0.27	258.2±3.11	220.9±4.54	655.5±8.2	13.71±0.84	11.22±0.17	0.89±0.01
MAY	33.58±6.5	6.62±0.04	1086.1±10.3	5.65±0.37	5.14±0.34	260.9±5.17	249.0±5.50	644.8±5.09	16.63±0.58	11.30±0.18	0.95±0.03
JUN	32.28±5.2	6.56±0.08	1129.8±21.1	4.94±0.45	5.95±0.41	277.1±7.15	265.1±4.71	654.8±4.07	16.98±0.51	11.52±0.10	1.07±0.06
JUL	31.10±4.8	6.38±.0.05	1204.2±10.7	4.62±0.48	4.97±.0.25	257.7±4.91	224.5±4.56	650.2±8.97	15.74±0.52	12.54±0.29	0.98±0.02
AUG	28.30±6.1	6.35±0.12	1131.8±25.1	5.21±0.39	4.80±0.33	253.1±6.35	211.7±4.15	624.8±4.20	15.35±0.18	11.94±0.25	1.05±0.04
SEPT	27.12±5.4	6.47±0.17	1089.5±18.5	5.54±0.34	4.19±0.18	243.8±3.68	213.4±4.85	581.7±4.81	13.17±0.15	11.51±0.29	1.40±0.03
OCT	22.60±5.2	7.14±0.11	1047.9±204	6.28±0.49	4.14±0.74	242.4±2.89	200.8±6.29	574.6±3.47	13.47±0.50	11.19±0.17	0.88±0.01
NOV	15.94±6.18	7.20±0.09	951.8±10.6	6.49±0.55	3.20±0.27	220.2±4.20	177.1±6.63	554.6±3.28	12.71±0.89	11.20±0.21	0.85±0.01
DEC	8.85±5.84	7.33±0.09	863.7±21.8	6.71±0.51	2.59±0.55	195.9±3.70	134.6±5.55	471.8±3.52	11.54±0.46	11.15±0.19	0.80±0.01
Mean	**22.07±9.05**	**6.85±0.36**	**1008.46± 125.95**	**5.90± 0.71**	**3.86±1.26**	**238.94± 26.50**	**193.87± 45.24**	**589.22± 77.49**	**13.60±2.19**	**11.43± 0.40**	**1.034± 0.28**

Table 2: Overall Index of Pollution (OIP) of water (Sargoankar and Deshpande, 2003; modified after BIS, 2012: IS-10500).

Category	Class Index	pH	E. Cond. (μmho. 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})	F^- (mg.L^{-1})
Excellent (C1)	1	6.5–7.5	500	9.5-10.5	1.5	75	75	500	150	20	1.2
Good (Acceptable) (C2)	2	6.0–6.5 and 7.5–8.0	750	8.5-11.5	3	150	150	1500	250	45	1.5
Slightly polluted (C3)	4	5.0–6.0 and 8.0–9.0	1000	6.5-12.5	6	300	300	2100	600	50	2.5
Polluted (C4)	8	4.5–5.0 and 9.0–9.5	2000	3.0-15.5	12	500	500	3100	800	100	6.0
Heavily polluted (C5)	16	<4.5 and >9.5	>2000	<3.0 and >15.5	24	>500	>500	>3000	>800	200	>6.0

Table 3: Calculation of Overall Index of Pollution (OIP) and Water Quality Index of Rani Pond, Deo at Aurangabad, Bihar, India (A=Mean, B=Minimum and C=maximum) (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
1.	pH	A	7.5	7.0	6.85	30	1.0	0.1646	4.938
		B	7.5	7.0	6.35	130	1.0	0.1646	21.40
		C	7.5	7.0	7.33	66	1.0	0.1646	10.86
2.	DO (mg.L^{-1})	A	5	14.6	5.90	90.63	8.0	0.2469	22.37
		B	5	14.6	4.62	103.96	8.0	0.2469	25.67
		C	5	14.6	6.83	80.94	4.0	0.2469	19.98
3.	TA (mg.L^{-1})	A	200	0	238.94	119.47	4.0	0.0062	0.741
		B	200	0	195.9	97.95	4.0	0.0062	0.607
		C	200	0	277.1	138.55	4.0	0.0062	0.859
4.	HA (mg.L^{-1})	A	200	0	193.87	96.94	4.0	0.0062	0.601
		B	200	0	133.20	66.61	2.0	0.0062	0.413
		C	200	0	265.10	132.55	4.0	0.0062	0.822
5.	TDS (mg.L^{-1})	A	500	0	589.22	117.84	2.0	0.0025	0.295
		B	500	0	411.20	82.24	1.0	0.0025	0.206
		C	500	0	655.50	131.10	2.0	0.0025	0.328
6.	Cl^- (mg.L^{-1})	A	250	0	13.60	5.44	1.0	0.0049	0.266
		B	250	0	10.69	4.28	1.0	0.0049	0.209
		C	250	0	16.98	6.79	1.0	0.0049	0.333

7.	NO_3^- ($mg.L^{-1}$)	A	45	0	11.43	25.40	1.0	0.0247	0.627
		B	45	0	11.15	24.78	1.0	0.0247	0.612
		C	45	0	12.54	27.87	1.0	0.0247	0.688
8.	BOD ($mg.L^{-1}$)	A	5.0	0	3.86	77.20	4.0	0.4115	31.77
		B	5.0	0	2.10	42.00	4.0	0.4115	17.28
		C	5.0	0	5.95	119.0	8.0	0.4115	48.97
9.	Fluoride ($mg.L^{-1}$)	A	1.0	0	1.034	103.4	1.0	1.2346	127.66
		B	1.0	0	0.800	80.0	1.0	1.2346	98.77
		C	1.0	0	1.140	114.0	2.0	1.2346	140.75
10.	EC	A	500	0	1008.46	201.69	8.0	0.0041	0.827
		B	500	0	803.50	160.7	4.0	0.0041	0.659
		C	500	0	1204.20	240.84	8.0	0.0041	0.987
		A				Mean OIP Score=	3.40	ΣWQI =	190.09
		B					2.70		165.83
		C					3.50		224.58
Annual average of Overall Index of Pollution (OIP) and water quality index (WQI) of Rani Pond, Deo at Aurangabad, Bihar, India							3.2		193.5

Table 4: Water Quality Rating as per Weight Arithmetic Water Quality Index Method.

Value of WQI	Rating of water quality	Grade	Value of WQI	Rating of water quality	Grade
<50	Excellent water quality	A	50-100	Good water quality	B
100-200	Poor water quality	C	200-300	Very poor water quality	D
>300	Unsuitable water quality	E	-	-	-

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