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Risk assessment and analysis of water quality in Ramgarh Lake, India

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ABSTRACT

The present study intended to comprehensive analysis of water quality and human health risk assessment in water of the Ramgarh Lake of Uttar Pradesh (U.P), India during the post monsoon season in year 2014. The analysis has been performed using pollution indices such as comprehensive pollution index (CPI), Carlson's trophic state index (C-TSI), eutrophication index (EI), organic pollution index (OPI) and hazard index (HI) based on the physiochemical parameters (DO, BOD, COD etc.) for ten different sites to ascertain the quality of water for public consumption and other life supporting activities. The results indicate that the Ramgarh Lake comes under the category of severely polluted (CPI>2.0), hypereutrophic (C-TSI>70), eutrophication (EI>1) and heavily organic pollutant load (OPI>4). Therefore, the water of Lake is not suitable for irrigation and life supporting for flora and fauna. In the present study, it has been analyzed that the CPI, OPI, EI, CTSI and HI are the best indices for assessment of human health risk and water quality in the water bodies.

Keywords: Ramgarh Lake, water quality, risk assessment, CPI, HI

INTRODUCTION

Water is the most essential life-supporting factor in each cell (microcosm) of an organism, ecosystem, and the universe.[1] Beside this, the freshwater is utilized by human for various purposes such as in drinking, several domestic, industrial, agricultural etc. India is naturally supported by a large number of freshwater bodies in the form of rivers, lakes and wetland. But in the recent years, due to excessive uses and careless extraction of water has severely degraded the water courses at different levels.[2] The prolonged discharge of untreated industrial effluents, domestic sewage and solid wastes has caused the severe pollution in water bodies and also created the human health problems.[3-6] In developing countries, about 1.8 million people die every year as a result of water related diseases.[7] Therefore, to bring out the aquatic ecosystems back to the balanced physicochemical, biological and hydro morphology features i.e. a good environmental status, it has become essential to promote sustainable use of the water resource in time.[8-9] In this concern, water quality is the best explanation of physiochemical and biological characteristics of water in reference to natural or standard quality, human health effects, and intended use.[10-13] Therefore, to classify the water quality and assess the risk to human health, numbers of methodologies like Oregon Water Quality Index (OWQI)[14] comprehensive pollution index (CPI),[15-18] organic pollution index (OPI),[19] eutrophication index (EI),[20] Horton's Index,[21] hazard index (HI)[22] etc. has been formulated by different researchers depending on informational goals, the sample type and the size of the sampling area.[23] The use of these indices in monitoring programs has been potential to inform the general public and decision-makers about the state of the ecosystem. The Gorakhpur city of U.P in India has a number of perennial lakes which are sources of fresh water for the local population. The Ramgarh Lake which is situated in Gorakhpur district of U.P, India is an important source of water for bathing, aesthetic, agricultural and industrial use by the local population. However, in last couple of years, Ramgarh Lake has been blocked by accumulation of silt or by the stocking of pollutants of all kinds.[24] Therefore, in the present study, an attempt has been made for the comprehensive analysis of the water quality of Ramgarh Lake and also assess the human health risk based on physiochemical parameters like DO, BOD, COD, etc and heavy metals (Fe, Cu, Mn) using CPI, OPI, EI, CTSI and HI.

SITE DESCRIPTION

The Ramgarh Lake is located on the south east of the Gorakhpur city of U.P in India. It is a eutrophic perennial lake, receives major water supply during rainy season, in

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addition, an east canal at the western end of the lake supplies water from Rapti River, which is now being regulated discontinuously by construction of band. The Gordhya nalla which carries water from residential areas of about 16 km joins the lake in the northern side. The outfall discharge of lake joins Gurrah nala which finally merges into Rapti River. The salient features of Ramgarh Lake and location map of sampling points has been shown in Table 1 and Figure1 respectively.

Table 1. Salient features of Ramgarh Lake

SNo	Salient features	Description
1.	Location	Gorakhpur city
2.	Coordinates	$26^0 42'30''$ to$26^0 44'55''$ N and $83^0 23'07''$ to $83^0 25'0''$ E
3.	Area of lake	6.78 km^2
4.	Perimeter	14 km
5.	Maximum depth	3.30 m
6.	Total storage capacity	7.36×10^6 m^3
7.	Annual average rainfall	1245 mm

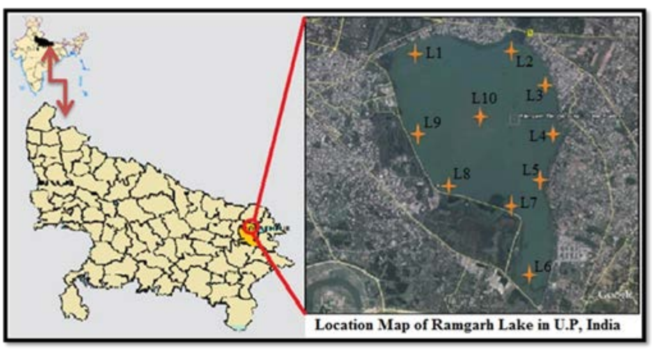

Figure 1. Sampling locations in Ramgarh Lake

DATA COLLECTION AND ANALYSIS

The water samples collected during post monsoon months in year 2014 from various sampling locations were tested and analyzed in laboratory as per the APHA[25] for various water quality parameters like pH, electrical conductivity (EC), total suspended solid (TSS), surface water temperature (WT), total hardness (TH), chemical oxygen demand (COD), biological oxygen demand (BOD), dissolved oxygen (DO), nitrate (NO_3), nitrite (NO_2), dissolved inorganic phosphate (DIP), dissolved inorganic nitrogen (DIN), potassium (K), turbidity, sulphate (SO_4) chloride (Cl), alkalinity, secchi disk (SD), chlorophyll-a (CA) and heavy metals like Fe, Cu and Mn.[22] The SD, DO, WT and pH were tested at sampling while other parameters were analyzed in laboratory. The mean and standard deviation of all the parameters with their measurement unit and analytical methodologies have been briefly described in table 2.

ASSESSMENT METHODS

The data obtained during laboratory analysis were used in evaluation of five different indices to classify the status of water pollution and the tropic state of the Lake. The equations to evaluate indices are shown in table 3.

Table 2: Water quality parameters analyzed during study

Parameters	Unit	Pre-monsoon (Mean ± SD)	BIS 1991	WHO 2011	Analytical method
pH	–	9.30 ± 0.36	6.5-7.5	6.5-7.5	pH meter
EC	ms/cm	0.53 ± 0.02	–	300	Electrometric
WT	^{0}C	30.00 ± 0.82	–	40	Thermometric
TH	mg/l	126.10 ± 14.05	300	500	Titrimetric
COD	mg/l	150.52 ± 23.52	–	20	Electrometric COD meter
Turbidity	ntu	5.70 ± 0.48			Nephelometric method
BOD	mg/l	48.60 ± 15.43	–	5	5 days incubation, 20°C
DO	mg/l	8.00 ± 1.34	–	>5	Electrometric DO meter
TSS	mg/l	28.20 ± 14.28	100	–	Filtration and Gravimetric
Nitrate	mg/l	0.62 ± 0.52	45	10	Hach Spectrophotometric
Nitrite	mg/l	0.34 ± 0.62	0.06	0.06	Hach Spectrophotometric
DIP	mg/l	0.58 ± 0.16	–	5	Hach Spectrophotometric
Cl	mg/l	60.84 ± 4.88	250	250	Argentometric Titration
SO4	mg/l	5.43 ± 3.82	150	150	Hach Spectrophotometric
DIN	mg/l	0.96 ± 0.69	45.06	10	Hach Spectrophotometric
Alkalinity	mg/l	231.00 ± 33.81	200	200	Titrimetric
K	mg/l	10.70 ± 1.70	200	200	Hach Spectrophotometric
SD	meter	0.40 ± 0.08	–	–	Using a Secchi Disk
CA	µg/l	0.083 ± 0.029	–	–	Acetone Extraction
Fe	mg/l	0.24 ± 0.26	0.3	0.3	Hach Spectrophotometric
Cu	mg/l	0.18 ± 0.08	0.05	0.05	Hach Spectrophotometric
Mn	mg/l	0.32 ± 0.16	0.1	0.1	Hach Spectrophotometric

[A] COMPREHENSIVE POLLUTION INDEX (CPI)

CPI is evaluated by using measured concentration of all the water quality parameter w.r.t to their permissible limit in drinking water quality prescribed by BIS[26] and WHO[27], to classify the overall water quality status of lake and its suitability for human use.

[B] ORGANIC POLLUTION INDEX (OPI)

The measured concentrations of COD, DO, DIN and DIP are used to evaluate OPI w.r.t to their permissible limit in drinking water quality prescribed by BIS[26] and WHO[27], to classify the organic load or pollution due to organic compounds in the lake.

Table 3: Indices used in assessing risk and pollution of water on lake

Indices	Equation	Descriptions
Comprehensive pollution index (CPI) [15-16-17-18]	$CPI = \frac{1}{n}\sum_{i=1}^{n} PI$ $PI = \frac{\text{Measured concentation of individual parameter}}{\text{Standard permisible concentration of parameter}}$	Clean (0-0.20) Sub clean (0.21-0.4) Slightly polluted (0.41-1.00) Moderately polluted (1.01-2) Severely polluted (≥2.01)
Organic pollution index (OPI) [19]	$OPI = \frac{COD}{COD_s} + \frac{DIN}{DIN_s} + \frac{DIP}{DIP_s} - \frac{DO}{DO_s}$	<0: Excellent 0-1: Good 1-2: Begin to be contaminated 2-3: Lightly polluted 3-4: Moderately polluted 4-5: Heavily polluted
Eutrophication Index (EI) [20]	$EI = \frac{COD \times DIP \times DIN}{4500} \times 10^6$	>1: Eutrophication <1: No Eutophication
Carlson Trophic Index (C-TSI)[28-29]	CTSI (CA) = 9.81In CA+30.6 CTSI (SD) = 60-14.41ln (SD) CTSI (TP) = 14.42 In TP + 4.15 CTSI = [TSI (TP) +TSI (CA) +TSI (SD)]/3	<30 -40: Oligotrophic 40-50: Mesotrophic 50-80: Eutrophic > 80: Hyper eutrophic
Hazard Index (HI) [22]	ADD= Ci × IR × ED× EF/BW× AT HQ= ADD/RFD $HI = \sum HQ$	<1: Acceptable risk of cancer >1: Unacceptable risk of cancer

Table 4: Parameters to evaluate the ADD value

SNo	Risk Parameters	Sym bols	Units	Value
1	Concentration	Ci	mg/l	See Table 1
2	Exposure duration[30]	ED	Years	30
3	Exposure frequency[30]	EF	Days/yea r	350
4	Average time[31]	AT	Years	68.13
5	Body weight[31]	BW	Kg	51.9
6	Ingestion rate[32]	IR	L/day	2
7	Reference chronic dose[33]	RFD	Mg/kg-day	Fe (0.7); Cu (0.04); Mn (0.14); NO_3 (1.6); NO_2 (0.1).

[C] EUTROPHICATION INDEX (EI)

EI was developed to classify the water pollution in the water bodies due to algal biomass. The evaluation of this index involves data of COD, DIN and DIP to define the eutrophic state of the lake.

[D] CARLSON'S TROPIC STATE INDEX (CTSI)

In order to validate the EI result, CTSI has been evaluated. It requires the data of chlorophyll-a, nitrogen, phosphorus and secchi depth to understand and define the tropic state of lake. It is relatively simple and easy for both in theory and use. It is an ideal method for use in volunteer programs.

[E] HAZARD INDEX (HI)

Risk assessment or the probability of occurrences of adverse human health effects due to exposures to environmental hazards over a particular time period can be classified by HI range. In the present study, the health risk from lake water consumption was assessed w.r.t its carcinogenic as well as non-carcinogenic effects using the measured concentration of Fe, Cu, Mn, nitrate and nitrite which has been used for evaluation of HI. The exposures parameters required for risk assessment are obtained from risk assessment information system (RAIS),[28] shown in table 4.

RESULTS AND DISCUSSIONS

The measured concentrations of water quality parameters for post monsoon sampling season were analyzed during laboratory testing and compared to the standard permissible concentration of drinking water quality prescribed by BIS and WHO. A wide variation has been found for the measured concentration of all parameters to the required standard. Therefore, to assess the human health risk and water pollution in lake, the measured data of parameters were used to evaluate CPI, OPI, EI, CTSI and HI. The result of these indices at all 10 sampling locations is shown in table 5. The CPI results were found to vary in the range 1.61 to 3.17, whereas the average CPI of the lake was found as 2.23 i.e. severely polluted (CPI> 2.01). The variation of the PI value of all parameters considered is shown in figure 2. The minimum CPI was evaluated as 1.61 only at location L10 i.e. slightly polluted. Similar result was also obtained with OPI,

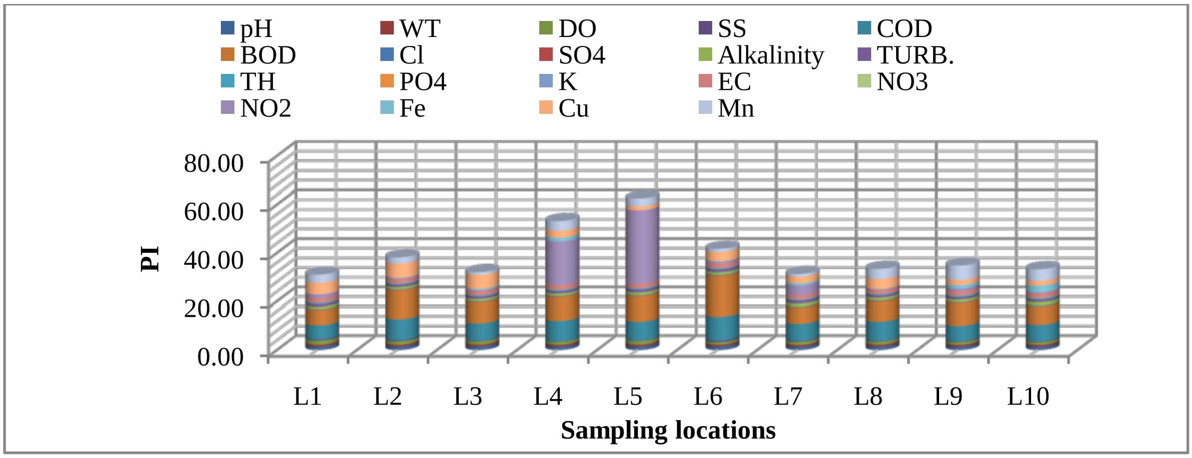

Figure 2. PI values of water quality parameters

Table 5: Indices values to classify the risk and pollution of water in Ramgarh Lake

Sampling locations	CPI	Polluted	OPI	Organic pollution	EI	Eutrophication	TSI	State	HI	Human cancer risk
L1	2.06	Severely	5.81	Heavily	1.41	Eutrophication	82	Hypereutrophic	3.78	Unaccepted
L2	2.15	Severely	7.18	Heavily	7.88	Eutrophication	80.12	Hypereutrophic	8.08	Unaccepted
L3	2.04	Severely	5.78	Heavily	1.50	Eutrophication	81.32	Hypereutrophic	3.40	Unaccepted
L4	2.71	Severely	7.29	Heavily	1.63	Eutrophication	83.58	Hypereutrophic	2.75	Unaccepted
L5	3.17	Severely	6.25	Heavily	1.38	Eutrophication	77.66	Hypereutrophic	2.34	Unaccepted
L6	2.12	Severely	8.88	Heavily	4.13	Eutrophication	80.93	Hypereutrophic	3.70	Unaccepted
L7	2.12	Severely	5.88	Heavily	3.51	Eutrophication	78.66	Hypereutrophic	3.49	Unaccepted
L8	2.17	Severely	6.70	Heavily	1.37	Eutrophication	78.11	Hypereutrophic	3.26	Unaccepted
L9	2.19	Severely	5.33	Heavily	2.05	Eutrophication	81.51	Hypereutrophic	3.18	Unaccepted
L10	1.61	Moderately	4.13	Moderately	1.21	Eutrophication	83.27	Hypereutrophic	1.90	Unaccepted

which is found to vary in the range of minimum 4.13 at L10 to maximum 8.88 at L6 i.e. heavily polluted due to organic pollutant.

To define the eutrophic state of the Lake, EI was evaluated. The EI value was in range >1 i.e. eutophication at all sampling locations. In order to validate EI outcome further, the CTSI was calculated on the entire sampling site and was found in the range of 77.22 at L8 to 83.58 at L4 is an indication of hypereutophic conduction of the lake. The variation of CPI, OPI, EI and CTSI at all sampling locations is shown in figure 3.

In figure 3, it has been found that the variation in OPI, EI and CTSI at the entire sampling site is due to varying concentration of limiting nutrient nitrogen, phosphorus and SD during post monsoon season in the Ramgarh Lake. Whereas the CPI was found to be almost similar at all sampling locations except at L10, which might be due to the location i.e. middle of the lake that supports dilution of water and balancing of the nutrients. The risk analysis for human health has been performed using HI evaluation method at all sampling locations in the lake. The HI was found in range >1 at all sampling locations i.e. unacceptable risk of cancer. From these results, it has been found that overall water quality of the study stretch is severely polluted and hypereutrophic i.e. not suitable for human use and cannot support life as evidenced by high EI, OPI, CPI and C-TSI observed in both the seasons. It has been recommended that there can be an unaccepted carcinogenic risk to human (as HI>1) if the Lake water is used for drinking purpose.[29-35]

CONCLUSION

The present study is based on the CPI, OPI, EI and C-TSI in the study stretch of Ramgarh Lake, India using various water quality parameters like DO, BOD, COD etc. The result reveals that the overall water quality of lake is

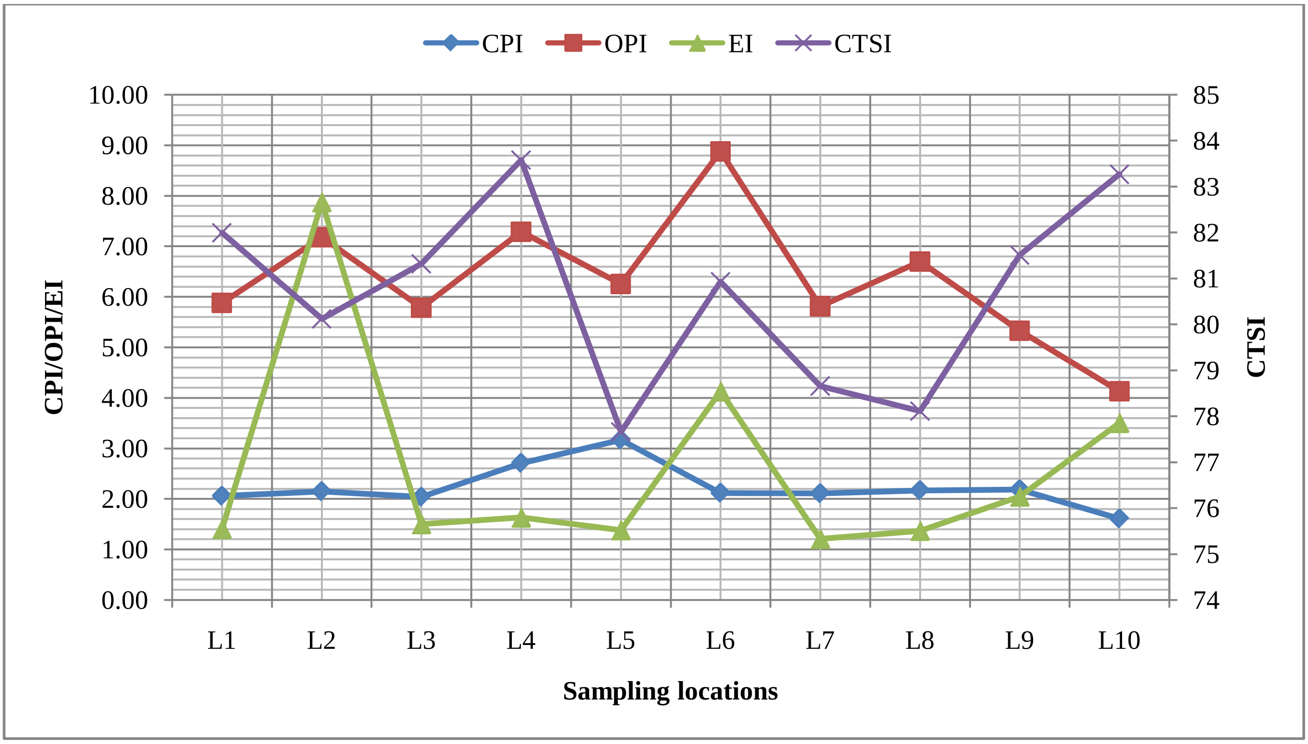

Figure 3: Variations of pollution indices at various sampling locations

severely polluted, hypereutrophic and has no life support activity, in post-monsoon season. The risk assessment for human health was found to have unacceptable risk of carcinogenic effect if water is used for drinking as the HI was found to be in range >1 at all sampling locations. Therefore, it is recommended that for conservation of the Ramgarh Lake, the concerned authorities and institutions to water pollution should take immediate remedial measures to prepare and implement a conservation plan, also carry out regular monitoring of water quality. Further, it is recommended that the CPI, OPI, EI, CTSI and HI are the best indices for assessment of human health risk and water quality status in the water bodies. The present study could be valuable in the preparation and execution of a conservation plan.

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