J. Mater. Environ. Sci. 7 (Y) (2016) 713-719
ISSN: 2028-2508
CODEN: JMESCN

Assessment of Surface Water Quality in Surha Lake using Pollution Index, India

Saurabh Mishra[1*], M. P. Sharma[2] and Amit Kumar[3]
[*1, 2, 3] *Biomass and ecosystem lab, Alternate Hydro Energy Centre, Indian Institute of Technology Roorkee, Uttarakhand, 247667, India*

Received 01 Jun 2015, Revised 29 Nov 2015, Accepted 14 Dec 2015
**Corresponding author: saurabhmishra20057@gmail.com, Mol. No: +91-7417575326*

Abstract
The present study aims to assess the surface water quality in Surha Lake using CPI, OPI, EI and TPI with respect to drinking water, during wet and dry seasons in the year 2014-15. The results indicate that water quality in the lake is moderately polluted and eutrophic i.e. in CPI range 1-4 and EI>1. The TPI was found in the range TPI >1 which signifies the severely contaminated lake water due to trace metals. Therefore, the lake water is not suitable for drinking and it is suggested to do prior treatment of lake water before use. It is recommended to the concerned authority to prepare and implement a proper monitoring program and carry out conservation strategies to restore the water quality of the lake and reduce its ill effects.

Keywords: Surha Lake, CPI, TPI, Drinking water.

1. Introduction
In the recent time, the deterioration of water quality in the surface water bodies due to anthropogenic activities like rapid urbanization and increased agricultural runoff has become a serious worldwide problem [1]. In the developing country like India which is naturally gifted with large number of rivers, lakes, wetland and ponds, facing the scarcity of useful water in many parts of the country due to over exploitation of these water sources [2-3]. Therefore, it has become essential to assess the water quality changes in a water body to identify the pollutants, categorize the water use and strategize the remedial measures to maintain the ecological health and restore the carrying capacity of the water body. Over the last few decades, in order to assess the water quality in a water body, researchers from the different parts of the world have developed a number of methodologies like NSFWQI [4], Water Quality Index of Central Pollution Control Board [5], comprehensive pollution index (CPI) [6-8] Overall Index of Pollution [9], eutrophication index (EI) [10], organic pollution index (OPI) [11], etc. based on the water quality parameters. However, there is no any universal water quality assessment model available which can be widely acceptable and comparable [12]. The present study is focused to assess the water quality in Surha Lake which is located in district Ballia of U.P in India using pollution indices CPI, OPI, EI and TPI. Based on the literature review, it has been found that a number of studies have been conducted to assess diversity of fishes [13], identification of zooplanktons, diversity of aquatic insects and molluscan fauna, [14-15], and analysis of aqua status of the lake [16] in catchment of Surha Lake. But, a comprehensive study of water quality based on physiochemical parameters and trace metals has not been carried out. The trace metals, which are among the most persistent pollutants that get accumulated in the biota and enters into the food chain cause human health risk of cancer at higher concentration [17]. Therefore, the assessment of trace metal contamination in surface water of the Surha Lake using TPI has also been reported in the present study.

2. Material and methods

2.1. Description of Study Site

The Surha Lake is an ox-bow lake located in the area of Jai Prakash Narayan Bird Sanctuary, which lies in the Indo-gangetic plain i.e. in the district Ballia of U.P, India at coordinates of $26^0$40' to $26^0$42' E and $84^0$11' to $84^0$14' N. During the rainy season, it covers a catchment area of about 34.33 km^2 as the three small streams Katehar nala Gararai, and Madha that join the lake and drains the major water carrying from Saryu River (Ghaghra River) and Ganga. While in summer shrinks to about 11.23 km^2 and the rest of the area is used for crop cultivation by the local farmers. The area receives an average annual rainfall of about 1000 mm with maximum of 43^0C in summer and a minimum temperature of 4^0C in winter. The water of the lake is used by the local population for various purposes like drinking, bathing, agriculture, fisheries, etc. and also the only source of survival for the rich bird species in the area. A location map of the Surha Lake with the marked water sampling locations is shown in Figure 1 and the details of locations are given in Table 1.

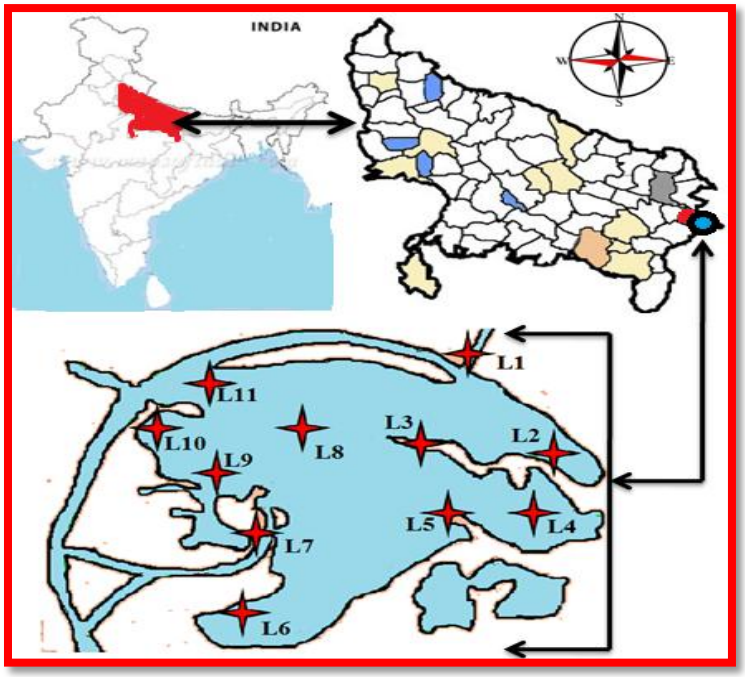

Figure 1: Location map of Surha Lake in U.P, India

Table 1: Details of sampling locations

S. code.	Sampling locations	Coordinates
L1	Maritar	$84^0$19'11″ N to $25^0$86′11″ E
L2	Rajpur	$84^0$20′30″ N to $25^0$84′80″ E
L3	Kathar nala merge point 1	$84^0$18′20″ N to $25^0$85′11″ E
L4	Narayanpur	$84^0$20′31″ N to $25^0$83′81″ E
L5	Kathar nala merge point 2	$84^0$18′90″ N to $25^0$83′70″ E
L6	Fulwaria	$84^0$16′50″ N to $25^0$82′41″ E
L7	Bhikampur Medha nala merge point	$84^0$16′81″ N to $25^0$85′31″ E
L8	Middle of lake	$84^0$17′10″ N to $25^0$85′30″ E
L9	Basantpur	$84^0$16′11″ N to $25^0$84′51″ E
L10	Shivpur	$84^0$15′30″ N to $25^0$85′21″ E
L11	Kaithauli	$84^0$15′91″ N to $25^0$85′90″ E

2.2. Data Collection and Analysis

The sub surface water samples were collected and analyzed during wet and dry seasons in year 2014-15 at L1, L2, L3…..L11 sampling locations in the Surha Lake. The water quality parameters like pH, dissolve oxygen (DO), electrical conductivity (EC) and surface water temperature (WT) were directly measured on site using portable equipments, and for further analysis, the collected samples were preserved at 4^0C and transported to laboratory within 24 hrs where the water quality parameters like BOD, TH, trace metals etc. were tested experimentally using analytical methodologies as per the APHA [18] and the results are shown in form of mean and standard deviation, for whole lake, in Table 2.

Table 2: Mean and standard deviation (SD) of the water quality parameters

S. No.	Parameters	Symbols	Units	Wet season (Mean±SD)	Dry season (Mean±SD)	Standard value (BIS & WHO)	Analytical methods
1.	Surface water temperature	WT	^{0}C	17.69±0.91	25.18±1.09	40	Thermometric
2.	Total dissolved solid	TDS	mg/l	172.56±30.20	182.75±36.70	500	Filtration and Gravimetric
3.	Total suspended solid	TSS	mg/l	46.00±4.29	47.82±5.31	100	Filtration and Gravimetric
4.	pH	pH	−	7.69±0.22	7.62±0.31	6.5-7.5	pH meter
5.	Nitrate	NO_3	mg/l	3.77±0.32	4.77±0.32	45	Hach Spectrophotometric
6.	Nitrite	NO_2	mg/l	0.04±0.00	0.05±0.00	0.06	Hach Spectrophotometric
7.	Dissolve oxygen	DO	mg/l	7.86±0.34	7.24±0.50	5	Electrometric DO meter
8.	Biochemical oxygen demand	BOD	mg/l	5.73±0.53	5.79±0.48	5	5 days incubation, 20°C
9.	Chemical oxygen demand	COD	mg/l	56.55±6.12	59.73±6.97	20	Open Reflux
10.	Phosphate	PO_4	mg/l	0.31±0.03	0.48± 0.03	5	Hach Spectrophotometric
11.	Turbidity	-	NTU	3.64±1.12	6.91±1.38	1	Nephelometric
12.	Chloride	Cl	mg/l	45.36±6.22	47.36±4.78	250	Titrimetric
13.	Calcium	Ca	mg/l	132.93±12.58	142.57±11.34	75	Titrimetric
14.	Magnesium	Mg	mg/l	207.98±19.27	246.53±26.97	30	Titrimetric
15.	Total hardness	TH	mg/l	340.91±30.73	389.09±35.90	300	Titrimetric
16.	Sulphate	SO_4	mg/l	15.45±2.02	14.55±1.37	150	Hach Spectrophotometric
17.	Potassium	K	mg/l	4.89±0.53	5.11±0.58	200	Hach Spectrophotometric
18.	Total alkalinity	T-Alk	mg/l	224.73±12.15	279.00±35.32	200	Titrimetric
19.	Electrical conductivity	EC	µS/cm	265.91±38.48	250.18±46.27	300	Electrometric conductivity meter

2.3. Comprehensive Pollution Index (CPI)

It is an essential tool to assess the water quality of a water body [19]. The calculation is based on the physiochemical parameters data obtained during laboratory testing of the collected water samples and is mathematically expressed as.

$$PI_i = \frac{C_i}{S_i} \quad \text{Equation 1}$$

$$CPI = \frac{1}{n}\sum_{i=1}^{n} PI \quad \text{Equation 2}$$

Where, PI is the pollution index of i^{th} parameter; C_i is the measured concentration of the i^{th} parameter; S_i is the standard permissible concentration of the i^{th} parameter in the water; and n is the total number of parameters. The standards permissible concentration of water quality parameters in drinking water prescribed by BIS and WHO [20-21] has been considered in the present study to check the suitability of water for drinking purpose. The CPI range from 0-2 and classifies water quality as: 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).

2.4. Organic Pollution Index (OPI)

It is an important tool to classify the water quality of a water body based on only four physiochemical parameters, i.e. COD, DO, dissolve inorganic nitrogen (DIN) and dissolve inorganic phosphate (DIP) [11] and is mathematically expressed as:

$$OPI = \frac{COD}{COD_s} + \frac{DIN}{DIN_s} + \frac{DIP}{DIP_s} - \frac{DO}{DO_s} \quad \text{.....Equation 3}$$

Where, the numerators (COD, DO, DIN and DIP) in the above equation are the measured concentration obtained during laboratory testing of collected water samples and the denominator are the standard permissible concentration in drinking water quality [20-21]. In this paper, sum of concentration of nitrate and nitrite has been used as DIN and phosphate as DIP. OPI range from 0-5 and classifies water quality as: excellent (<0); Good (0-1); polluted (1-4); heavily polluted (4-5).

2.5. Eutrophication Index (EI)

It is used to classify the eutrophication in the water body based on only three physiochemical parameters, i.e. COD, DIN and DIP [10] and is mathematically expressed as:

$$EI = \frac{COD \times DIP \times DIN}{4500} \times 10^6 \quad \text{..... Equation 4}$$

Where, COD, DIN and DIP are the measured concentration obtained during laboratory testing of collected water samples. In this paper sum of concentration of nitrate and nitrite has been used as DIN and phosphate as DIP. It classifies the water quality as: Eutrophication (>1); No Eutophication (<1).

2.6. Trace Metal Pollution Index (TPI)

It is a very useful methodology to assess the trace metal contamination in the water quality of the lake as it shows the composite pressure of individual trace metals on the overall quality of water [22] and is mathematically expressed as:

$$k = 1/\sum_{i=1}^{n} \frac{1}{X_i} \quad \text{..... Equation 6}$$

$$W_i = k/X_i \quad \text{..... Equation 7}$$

$$Q_i = T_i/X_i \quad \text{..... Equation 8}$$

$$TPI = \sum_{i=1}^{n} Q_i W_i / \sum_{i=1}^{n} W_i \quad \text{.....Equation 9}$$

Where, k is the proportionality constant; X_i is the standard permissible concentration of i^{th} trace metal, for drinking water quality [20-21]; W_i is the weightage factor of i^{th} metal; Q_i is the quality index of individual trace metal; T_i is the measured concentration of the i^{th} metal; n is the total number of metals. The TPI range from (0-1) and classifies the water contamination as: not contaminated (0< TPI ≤1) and severely contaminated (TPI>1).

3. Results and Discussions

The data of measured concentration of water quality parameters have been used to calculate the CPI, OPI, EI and TPI and results, shown in Table 3. The CPI was found to be in the category of moderately polluted water quality (CPI range 1-2) during both sampling seasons at all locations. It is also supported by the evaluation of

OPI, which was found in the range 1-4 i.e. polluted water quality of the lake. The lake water was found to be in eutrophic state, as calculated EI was in range >1 and also seems to be severely contaminated due to trace metals i.e. the calculated TPI was in range >1 at all locations in both seasons.

Table 3: Calculation results of water quality indices at all locations in wet and dry seasons

Sampling locations	CPI			OPI			EI			TPI		
	Wet	Dry	Polluted	Wet	Dry	Polluted	Wet	Dry	Eutrophic	Wet	Dry	Contaminated
L1	1.08	1.21	Moderate	1.24	1.39	Yes	3.25	5.46	Yes	6.24	6.26	Severely
L2	1.07	1.25	Moderate	1.18	1.40	Yes	3.43	5.70	Yes	6.19	6.16	Severely
L3	1.23	1.41	Moderate	1.80	2.30	Yes	5.45	9.15	Yes	6.09	6.46	Severely
L4	1.09	1.26	Moderate	1.22	1.65	Yes	3.43	6.11	Yes	5.78	5.83	Severely
L5	1.24	1.46	Moderate	2.04	2.37	Yes	6.17	9.80	Yes	5.88	5.99	Severely
L6	1.10	1.19	Moderate	1.36	1.68	Yes	3.43	6.17	Yes	6.14	6.03	Severely
L7	1.35	1.50	Moderate	2.12	2.58	Yes	6.28	10.06	Yes	6.08	6.52	Severely
L8	1.12	1.23	Moderate	1.21	1.43	Yes	3.43	5.81	Yes	5.78	5.83	Severely
L9	1.12	1.21	Moderate	1.09	1.38	Yes	3.37	5.70	Yes	5.92	5.97	Severely
L10	1.11	1.25	Moderate	1.18	1.52	Yes	3.62	6.17	Yes	5.66	5.80	Severely
L11	1.07	1.25	Moderate	1.11	1.46	Yes	3.36	5.81	Yes	5.78	5.78	Severely

The maximum value of CPI, OPI and EI was obtained at L7 location in both seasons while the maximum value of TPI was at L6 location in the wet season and at L7 location in the dry season. In order to check the change in water quality during wet and dry season, the CPI calculated at all locations was plotted graphically as shown in Figure 2.

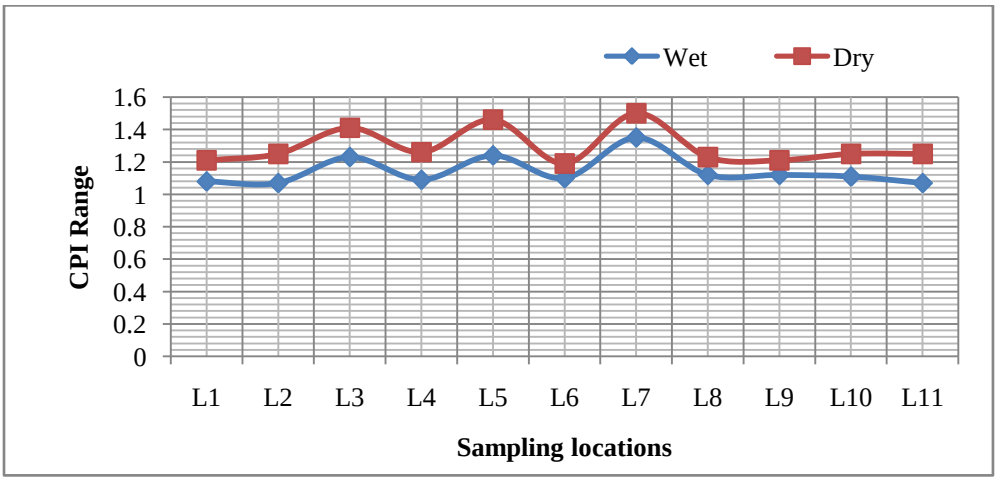

Figure 2: Variations of CPI at all sampling locations

From the Figure 2, it can be clearly observed that the calculated CPI was found to be more in the dry season than in the wet season at all locations. It indicates that the lake receives more amount of wastewater in the dry season and has less dilution of water that reduced the self sustained, carrying or assimilative capacity of the lake. The TPI calculated at all locations was plotted graphically and is shown in Figure 3.

The TPI value was observed to be almost similar at all locations in both seasons except at L3 and L7 locations, where TPI was more in dry season. The major variation of TPI at L3 and L7 locations may be due to joining

point of two major nallas, Kathar and Medha nalla, which carry wastewater from the urban and rural areas of district Ballia. Also, the lake receives heavy agricultural runoff that brings the trace metals to the lake. Therefore, on the basis of result obtained it has been revealed that the lake water is not suitable for drinking purpose and requires prior treatment before use. It has been suggested that the strategies like disilting, formation of bunds and channels around the lake to reduce direct input of runoff into the lake, interception and diversion of nallas so that the water joins the lake after de-sedimentation and nutrient trapping and freshwater supply to the lake should be adopted to enhance the proper dilution of lake water and maintaining the aeration to restore the water quality and carrying capacity of the lake.

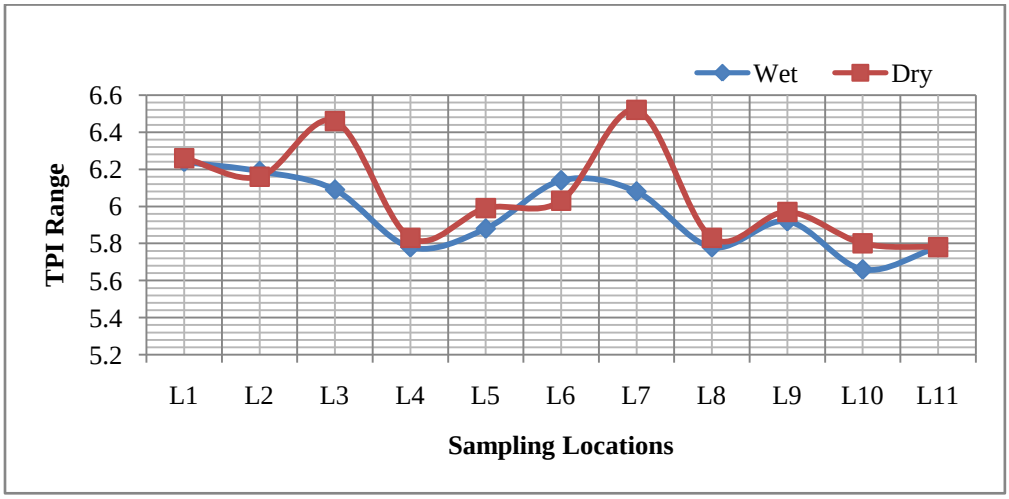

Figure 3: Variations of TPI at all sampling locations

Conclusions

On the basis of calculation of the CPI, OPI and EI related to drinking water quality, it has found that the lake water quality is moderately polluted and eutrophic i.e. it is not suitable for drinking purpose. Further, the calculated values of TPI obtained in range TPI>1, at all locations reveal that the water quality is severely contaminated due to trace metals. Therefore, it has been suggested that water quality must be prior treated before use and it has been recommended to the concerned authority, policy makers and stakeholders to prepare and implement a conservation plan, including the strategies to check the agricultural runoff by formation of bunds and channels around the lake and treatment of waste water before discharge into the lake. The present study could be beneficial in strategizing the monitoring program for conservation and restoration of lake.

Acknowledgement

The author (SM) is thankful to Ministry of Human Resource and Development (MHRD), Government of India for financial assistance in the form of academic scholarship during his Master of Technology programme in Environmental Management of Rivers and Lakes.

References

1. Yadav N. S., Kumar A., Sharma M. P., *J. Integ. Sci. Technol*. 2 (2014) 52-56.
2. Kumar A., Chaudhary O., *Inter. J. Emerg. Technol. Adv.* Engg. 3 (2013) 574-577.
3. Yadav N. S., Sharma M. P., Kumar A., *J. Mat. Environ. Sci*. 6 (2015) 613-618.
4. Kumar A., Sharma M. P., Yadav N. S., *J. Mat. Environ. Sci*. 5 (2014) 1781-1785.
5. Sarkar C., Abbasi S. A., *Environ. Monit.* Assess. 119 (2006) 201.

6. Jiang H. H., Zhu J. P., *Environ. Monit*. 15 (1999) 46-47.
7. You Z. J., Lu J. X., Liu Y. Y., *Nei. Environ. Sci*. 21 (2009) 101-102.
8. Guo M. M., *Environ. Sci. Manag*. 31 (2006) 175-178.
9. Sargaonkar A., Deshpande V., *Environ. Monit.* Assess. 89 (2003) 43.
10. Liu S., Lou S., Kuang C., Huang W., Chen W., Zhang J., Zhong G., *Marine Poll. Bull*. 62 (2011) 2220–2229.
11. Quan W. M., Shen X. Q., Han J. D., Chen Y. Q., *Marine Environ. Sci*. 24 (2005) 13–16.
12. Shi J., Liu P. G., Zhang L. X., *Acta. Oceano. Sin*. 31 (2009) 99-105.
13. Pandey K. C., Agrawal N., Sharma R. K., *J. Appl. Nat. Sci*. 2 (2010) 22-25.
14. Sharma R. K., Agrawal N., *J. Appl. Nat. Sci*. 3 (2011) 295-297.
15. Sharma R. K., Soni D.K., *J. Environ. Res. Develop.* 7 (2013) 4A.
16. Sharma R. K., Agrawal, N., *J. Appl. Nat. Sci*. 4 (2012) 60-64.
17. Barnwal P., Mishra S., Singhal S. K., *J. Integr. Sci. Technol*. 3 (2015) 22-27.
18. APHA, AWWA and WPCF, (2005) 21st edition. American Public Health Association, Washington, DC.
19. Liu S., Zhu J. P., *Environ. Monit*. 15 (1999) 33-37.
20. BIS, (1999). Standards of Water for Drinking and Other Purposes Bureau of Indian Standards.
21. WHO (World Health Organization), (2011) Fourth edition. Water Sanitation and Hygiene Links to Health, WHO Press.
22. Reza R., Singh G., *Int. J. Environ. Sci. Tech.* 7 (2010) 785-792.