Int. Res. Adv. 2018, 5(1), 20-25 Article

INTEGRATED
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Assessment of water quality using Pollution-Index in the study stretch of river Chambal, India

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Received on: 24-Sept-2017, Revised on: 28-12-2017, Accepted and Published on: 03-Feb-2018

ABSTRACT

The present study is intended to ascertain the quality of water for public consumption and other life supporting activities by way of assessing pollution indices such as Carlson's trophic state index (C-TSI), eutrophication index (EI), organic pollution index (OPI) and comprehensive pollution index (CPI). The study has been carried out for ten different sites in River Chambal of Madhya Pradesh, India, during pre and post-monsoon 2014. This paper deals with the study on – "How environmental parameters impacts/affects the quality of river water". In this study, four pollution indices have been determined on the basis of 16physico-chemical parameters, which indicates that the River Chambal comes under the category of clear (CPI<0.8), oligotrophic (C-TSI<30-40), no eutrophication (EI<1) and excellent water quality (OPI<0). Results also show that the river water is suitable for irrigation and life supporting for flora and fauna. With slight treatment, the water can be made available for drinking as well. The present study shows that EI and OPI index are the best parameters to assess water quality since it gives precise results based on four water quality parameters.

Keywords: Eutrophication index, CPI, OPI, C-TSI, Pollution

INTRODUCTION

Degradation of water quality at different levels has increased substantially during the last century and isbeing polluted due to rapid industrialization, urbanization, and other developmental activities/processes. The degree of pollution is generally assessed by studying physical and chemical characteristics of the water bodies.[1] Several studies have been found related to rivers in India[2-6] but very little work has been found on River Chambal.[8] The River Chambal is one of the clean rivers in Northern India and is a habitat for a rich diversity of flora and fauna. Therefore, an attempt has been made to study water pollution in River Chambal using pollution indices. Various water quality indices such as, Comprehensive Pollution Index (CPI),[9-13] Organic Pollution Index (OPI),[14] Eutrophication Index (EI),[15] Horton's Index,[16] Prati's Implicit Index of Pollution,[17] McDuffie and Haney's River Pollution Index,[18] Diniu's Water Quality Index,[19] Oregon Water Quality Index,[20] Florida Stream Water Quality Index,[21] Overall Index of Pollution,[22] Pesce and Wunderlin's Water Quality Index,[23] Water Quality Index of Central Pollution Control Board,[24] River Pollution Index,[25] Universal Water Quality Index,[26] Simplified Water Quality Index,[27] Said et al. Water Quality Index,[28] British Columbia Water Quality Index (BCWQI),[29] National Sanitation Foundation Water quality index (NSFWQI),[30] Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI)[31-32] has been formulated all over the world which can be used to assess the quality of water within a particular area promptly and efficiently. There is no such widely accepted and comparable index which can assess the quality of water.[30-32] Therefore,the applicability and rationality of water quality assessment method have become one of the focus areasfor environmentalist and policy maker. Yadav et al.[33-34] found that the water quality in River Chambal of Madhya Pradesh was good which can serve the purpose of irrigation, bathing, aquaculture etc. except drinking for human consumption. However, the eutrophication in the river has become a worldwide serious environmental problem in recent years,[35] understanding the mechanisms of eutrophication in the river will help in theconservation and remediation of river eutrophication. Therefore, the present study focuses on the comprehensive assessment of water quality based on OPI, Carlson's trophic state index (C-TSI), CPI, and EI in the Chambal River situated in M.P, India, which gives more précised results compared to other indices discussed above.

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Cite as: *Int. Res. Adv., 2018, 5(1), 20-25.*

 ISSN 2456-334X http://pubs.iscience.in/ira

MATERIAL AND METHODS

[A] STUDY SITE

The River Chambal is a perennial river which originates near the Janapao temple at about 24 km south-west away from Mhow in M.P at an elevation of 854.35 m. The total length of Chambal River is 960 km with catchment area 143,219 Km^2, mean depth 10m and an average discharge of about 456m^3/s. The stretch of river contained in the National Chambal sanctuary extends up to a distance of 600 km downstream from Kota (Rajasthan) to the confluence of the River Chambal with the River Yamuna (Etawah) (a major tributary of River Ganga). In fact, this river forms the boundary between Rajasthan & M.P and M.P & Uttar Pradesh (U.P). The field study was conducted in an entire stretch of 59 km from Rajghat to Kussidghat, it is due to more endangered species are found in this region.Sampling location from R1 to R10 lies between the coordinates 77˚54'15.7" N-78˚19'14.5" N longitudes and 26˚39'33.5" E -26˚51'48.2" E as shown in Figure 1.

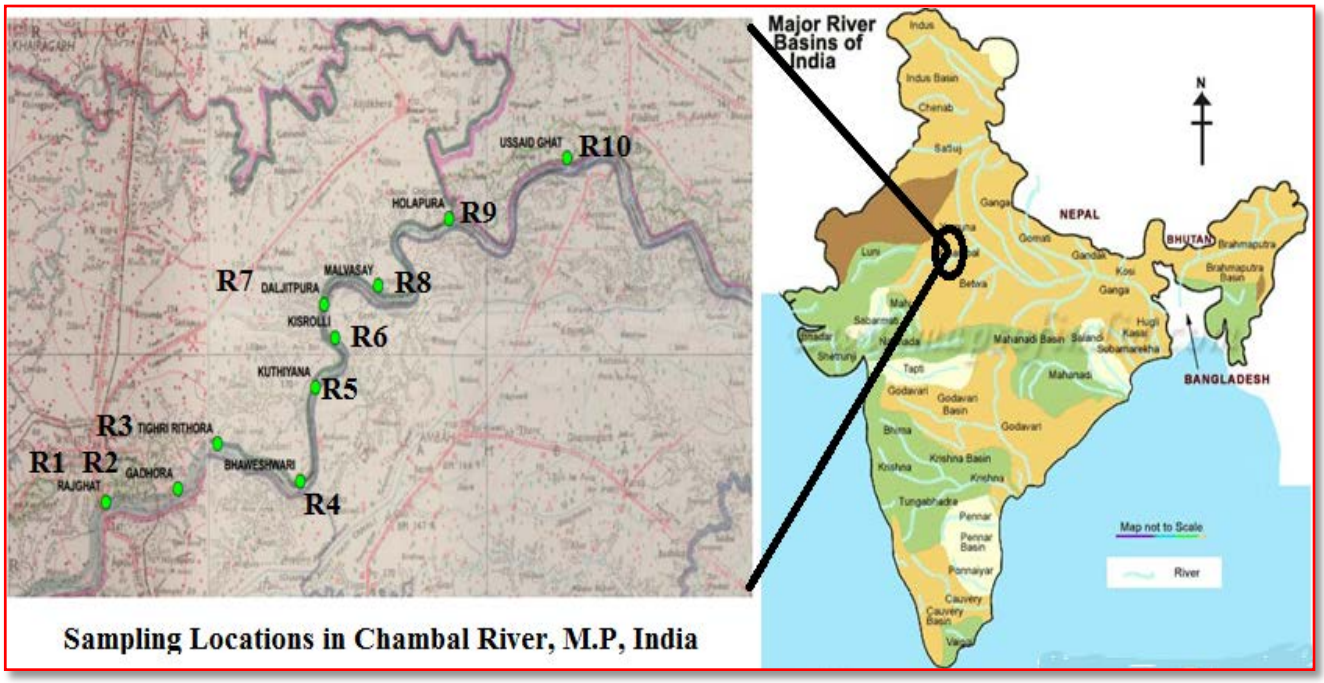

Figure 1: Map showing sampling location in River Chambal, India

The water samples were analyzed for various water quality parameters (pH, electrical conductivity (EC), total dissolved solid (TDS), surface water temperature (WT), total hardness (TH), chemical oxygen demand (COD), biological oxygen demand (BOD), dissolved oxygen (DO), total suspended solid (TSS), nitrate, dissolved inorganic phosphate (DIP), dissolved inorganic nitrogen (DIN), chloride (Cl), total coliform, river depth, chlorophyll-a (CA) as per standard procedures,[36] during pre and post-monsoon in year 2014 and these experimental values (mean ± SD) were compared with standard values recommended by Bureau of Indian standard (BIS) and World Health organization(WHO).[37-38] as given in Table 1.

[B] COMPREHENSIVE POLLUTION INDEX (CPI)

Based on the assessment of single factor index and considering the combined effect of all factors evaluated, CPI was calculated through different mathematical modelsand determines the pollution degrees by the appropriate method.[10-13] The CPI can be expressed by the formula given in Table 2.

[C]CARLSON TROPHIC STATE INDEX (C-TSI)

The nitrogen, phosphorus, and other biologically useful nutrients determine the trophic state of water body through TSI. Nutrients like nitrogen and phosphorus tend to limit the standing water bodies and the increased concentration tends to result in increased plant growth followed by corollary increase in subsequent trophic levels.[39]

[D] ORGANIC POLLUTION INDEX (OPI)

OPI index was developed by dividing the values of four parameters, COD, DIN, DIP, and DO.

[E] EUTROPHICATION INDEX (EI)

The EI is used for preliminary assessment of water quality of rivers/lakes/sea, which accounts for the effects of COD, DIN, and DIP. The EI above or equal to 1 in a water body indicates the condition of eutrophication due to excessive nutrients.

RESULTS AND DISCUSSIONS

The results of CPI, OPI, C-TSI and EIat 10 sampling sites in pre and post monsoon 2014 are shown in Table 3 and 4 respectively. The results shows that the OPI index varies between -1.26 to -1.49 whereas the mean OPI of -1.38 (OPI<0) indicates excellent water quality of River Chambal in pre-monsoon.

Furthermore, the OPI of post-monsoon varies between -1.34 to -1.55, whereas the mean OPI of the period is -1.48 (OPI<0),which also indicatesthe excellent quality of water. Average value of OPI was found to be decreasing from pre to post-monsoon, which mainly is on account of dilution of organic pollutant coming from

agricultural runoffs. The EI was calculated during pre and post-monsoon at all location and it was noted that it ranges from 0.0001 to 0.0007 and 0.0001 to 0.0011; whereas the average EI was found to be 0.0003 and 0.0005 respectively. In other words, EI<1 is an indication of no eutrophication during pre and post monsoonperiod.[40] But average EI was found to be increasing, which is due tothe contribution of agricultural runoff and anthropogenic activities in the nearby area. OPI and EI indicate that both organic pollution and eutrophication degree are much heavier in R8 and R10 sites than that in another site in both pre and post monsoon season, was due to the anthropogenic hindrances in study stretch.

Table 1: Comparative study of experimental water quality data with BIS and WHO

Sl. No.	Parameters	Unit	Pre-monsoon (Mean ± SD)	Post-monsoon (Mean ± SD)	BIS	WHO
1.	pH	□	7.40 ± 0.19	7.27 ± 0.19	6.5-7.5	6.5-7.5
2.	EC	µg/cm	903.50 ± 31.69	800.60 ± 97.24	□	300
3.	TDS	mg/l	535.20 ± 53.27	504.90 ± 44.12	500	1000
4.	WT	^{0}C	22.32 ± 1.13	23.09 ± 1.17	□	40
5.	TH	mg/l	234.70 ± 22.59	243.80 ± 22.62	300	500
6.	COD	mg/l	22.00 ± 4.85	20.60 ± 4.65	□	5
7.	BOD	mg/l	11.70 ± 2.11	11.27 ± 2.09	□	20
8.	DO	mg/l	7.86 ± 0.44	7.40 ± 0.41	□□	>5
9.	TSS	mg/l	58.20 ± 21.31	50.70 ± 20.21	100	□
10.	Nitrate	mg/l	0.03 ± 0.01	0.02 ± 0.01	45	10
11.	DIP	mg/l	0.02 ± 0.00	0.03 ± 0.01	□	5
12.	Cl	mg/l	49.44 ± 10.13	48.44 ± 10.47	250	250
13.	DIN	mg/l	0.49 ± 0.13	0.43 ± 0.24	45.06	10
14.	Total Coliform	MPN	445.00 ± 48.13	433.80 ± 49.92	0	0
15.	Depth	Meter	0.59 ± 0.14	0.57 ± 0.17	□	□
16.	CA	µg/l	0.17 ± 0.02	0.17 ± 0.02	□	□

The CPI was calculated at all sampling sites during pre and post-monsoon and it was found to be in the range of 0.54 to 0.66 and 0.52 to 0.64 respectively, whereas average CPI was found to be 0.61 and 0.58 i.e. CPI<0.80 is an indication of good quality of river water (concentrations accord with the standard). But, CPI was decreasing from 0.61 to 0.58 in pre to post-monsoon. The decrease in CPI value might be due to dilution of organic pollutant. The trophic index was calculated at the entire sampling site during pre and post-monsoon and it was found to be in the range of 25.20 to 37.62 and 28.23 to 36.00 respectively, whereas the average C-TSI was 31.21 and 31.65 i.e. C-TSI <30-40, is an indication of oligotrophic conduction of river which means water was clear and it could support life of aquatic flora and fauna.

The graphical presentation of all the indices has been shown in Figure 2.

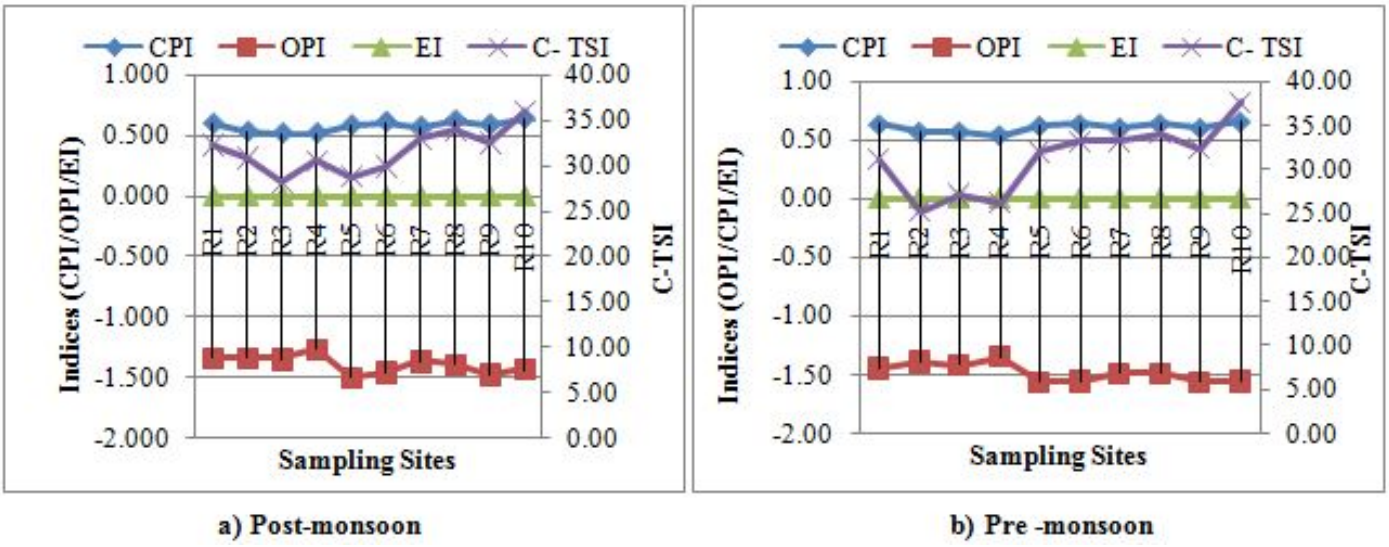

Figure 2: Pollution indices in River Chambal during post and pre-monsoon, 2014

Table 2: Descriptions of water pollution indices

Indices	Equations	Descriptions
Carlson Trophic Index (C-TSI)[27, 31]	TSI for CA; TSI = 9.81In CA+30.6 TSI for SD; TSI = 60-14.41ln (SD) TSI for TP; TSI = 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
Comprehensive pollution index (CPI)[4-7]	$CPI = \frac{1}{n}\sum_{i=1}^{n} PI$ $PI = \frac{\text{Measured concentation of individual parameter}}{\text{Standard permisible concentration of parameter}}$	C<0.8: Qualified; Some pollutants are detected but their concentrations accord with the standard. 0.8<C≤1.0: Basically quantified; Concentrations of some pollutants exceed the standard. 1.0<C≤2.0: Polluted; Concentrations of quite a part of pollutants exceed the standard. C>2: Seriously polluted; Concentrations of quite a part of pollutants exceed the standard many times.
Organic pollution index (OPI)[8]	$OPI = \frac{COD}{COD_s} + \frac{DIN}{DIN_s} + \frac{DIP}{DIP_s} + \frac{DO}{DO_s}$	<2: 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)[9]	$EI = \frac{COD \times DIP \times DIN}{4500} \times 10^6$	>1: Eutrophication <1: No Eutrophication
Where; CA (µg/l); SD (meter); TP (µg/l); COD_S, DIN_S, DIP_S, and DO_S are the standard concentrations as defined in BIS and WHO; PI is pollution index.		

Table 3: Pollutions indices at 10 sampling location during pre –monsoon 2014

Sampling Site	CPI	Status	OPI	Status	EI	Status	C- TSI	Status
R1	0.63	Qualified	-1.44	Excellent	0.0007	No Eutrophication	31.13	Oligotrophic
R2	0.57	Qualified	-1.39	Excellent	0.0001	No Eutrophication	25.20	Oligotrophic
R3	0.57	Qualified	-1.42	Excellent	0.0002	No Eutrophication	27.03	Oligotrophic
R4	0.54	Qualified	-1.34	Excellent	0.0001	No Eutrophication	26.20	Oligotrophic
R5	0.62	Qualified	-1.55	Excellent	0.0002	No Eutrophication	32.02	Oligotrophic
R6	0.64	Qualified	-1.55	Excellent	0.0004	No Eutrophication	33.24	Oligotrophic
R7	0.61	Qualified	-1.48	Excellent	0.0003	No Eutrophication	33.27	Oligotrophic
R8	0.64	Qualified	-1.48	Excellent	0.0007	No Eutrophication	34.08	Oligotrophic
R9	0.60	Qualified	-1.55	Excellent	0.0002	No Eutrophication	32.32	Oligotrophic
R10	0.66	Qualified	-1.55	Excellent	0.0004	No Eutrophication	37.62	Oligotrophic
Average	0.61	Qualified	-1.48	Excellent	0.0003	No Eutrophication	31.21	Oligotrophic

From the above Fig 2, it has been found that the variation in OPI, EI and CPI in pre to post-monsoon at the entire sampling site was due to dilution of organic pollutants in River Chambal. The C-TSI at R2 to R5 during post-monsoon shows more variation as compared to pre-monsoon, which might be due to temperature variation and little anthropogenic activity. So, these sites have slight better water quality in pre-monsoon. From these results, it has been found that overall water quality of the study stretch is excellent but at some of the locations, the water quality is slightly polluted than other locations. The results found were supported by our previous research paper.[9-15, 33-34]

It recommended that the water of the study stretch is not fit for drinking but suitable for irrigation, bathing, and can support a

large number of aquatic plants and animals as evidenced by low EI, OPI, CPI and C-TSI(Observed in both the seasons).

Table 4: Pollutions indices at 10 sampling location during post –monsoon 2014

Sampling Site	CPI	Status	OPI	Status	EI	Status	C- TSI	Status
R1	0.60	Qualified	-1.33	Excellent	0.0002	No Eutrophication	32.33	Oligotrophic
R2	0.53	Qualified	-1.33	Excellent	0.0002	No Eutrophication	30.94	Oligotrophic
R3	0.52	Qualified	-1.34	Excellent	0.0001	No Eutrophication	28.23	Oligotrophic
R4	0.52	Qualified	-1.27	Excellent	0.0005	No Eutrophication	30.54	Oligotrophic
R5	0.58	Qualified	-1.49	Excellent	0.0003	No Eutrophication	28.83	Oligotrophic
R6	0.61	Qualified	-1.45	Excellent	0.0006	No Eutrophication	29.96	Oligotrophic
R7	0.57	Qualified	-1.36	Excellent	0.0004	No Eutrophication	33.00	Oligotrophic
R8	0.62	Qualified	-1.39	Excellent	0.0009	No Eutrophication	34.00	Oligotrophic
R9	0.59	Qualified	-1.47	Excellent	0.0007	No Eutrophication	32.63	Oligotrophic
R10	0.64	Qualified	-1.43	Excellent	0.0011	No Eutrophication	36.00	Oligotrophic
Average	0.58	Qualified	-1.38	Excellent	0.0005	No Eutrophication	31.65	Oligotrophic

CONCLUSIONS

The present study is based on the CPI, OPI, EI and C-TSI in the study stretch of River Chambal, India using 16 water quality parameters.

The result reveals that the overall water quality of study stretch is excellent in both pre and post-monsoon.

The average C-TSI, OPI, EI and CPI during pre-monsoon were found as 0.61, -1.48, 0.0003 and 31.21 while in post-monsoon were 0.58, -1.38, 0.0005 and 31.65 respectively, which is an indication of the excellent and oligotrophic state of River Chambal. Therefore, the river water can be used for bathing, irrigation, and aquaculture. With prior treatment, river water can be made available for drinking as well. With the study, it can be concluded that the EI and OPI are the best pollution indices for assessment of water quality based on four parameters

ACKNOWLEDGMENTS

The author (NSY) 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.

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