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APPLICATION OF WATER QUALITY INDEX (WQI) AS A TOOL FOR ASSESSMENT OF POLLUTION STATUS OF SHIVNA RIVER AT MANDSAUR, M.P.INDIA

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ABSTRACT

Water from the River Shivna is the only source for drinking, agriculture and other domestic uses in Mandsaur of western Madhya Pradesh. The purpose of this study is to evaluate the surface water quality of River Shivna at Mandsaur in different seasons and at different segment of the River. A total of 225 samples, that is, 75 in winter, 75 in summer, and 75 in monsoon were collected from different sources for physicochemical analysis, and a WQI was calculated. The water quality values ranged 32.01-171.1The outcome of this study confirmed that most of the water samples were in poor condition (85.3%) and exceeded standard limits. We suggest that water is poor of quality in downstream and not entirely safe for drinking and requires prior treatment before consumption.

KEYWORDS: physicochemical parameters, Shivna River, water surface quality.

INTRODUCTION

Water is positioned as second essential factor after oxygen for all living organisms. Access to fresh water and hygiene services is a requirement to all the other internationally agreed goals and targets, including the eight Millennium Development Goals (MDGs) (UNEP.2015). Fresh water ecosystems are very important as they provide water for many human uses. But the coincident with rapid population and economic growth in the late 20th century various factors and mismanagement of the resources reduced biodiversity have altered the structure and function of rivers. Various physical, chemical and biological approaches are often measured as basic monitoring needs, as they can provide complete information for proper water management. (Metcalfe JL, 1993).The quality and availability of water have constantly played a significant role both in migration and in the quality of life. Accordingly, it is essential to test the water quality at regular time intervals or else contaminated water may cause a variety of waterborne diseases. The quality of surface water within an area is controlled by both natural anthropogenic (Jarvie et al., 1998; Liao et al., 2007; Mahavi et al., 2005; Nouri et al., 2008, Reddy, 2012a, b). For that reason, an effective and reliable assessment of the quality of surface waters is necessary for long term management of the surface water quality of the River (Dixon and Chiswell, 1996). The water quality index (WQI) is an efficient tool for the measurement of water pollution. It is a figure that merges several water quality factors into a single number and thus helps in understanding the quality of water with a single numerical value (Horton, 1965).

In India, 90% of the water supplied to the town and cities are polluted and out of which only 1.6% gets treated (CPCB, 2008).For that reason the supervision water quality is essential for the human welfare. WQI is an evaluation reflecting the combined influence of diverse water quality parameters and an effective tool to convey the information on the quality of water to the concerned civilians and policy makers. Therefore, the present study aims to provide information on the physicochemical characteristics of the water sources of the River Shivna at Mandsaur (Western Madhya Pradesh, India) in order to evaluate the appropriateness of the water for human consumption.

MATERIALS AND METHODS

Study area: Mandsaur district is located on northwest part of Madhya Pradesh state extends between the parallels of latitude 23 46’ and 24 45’ north and between meridians of longitude 74 44’ and 75 54’ east (Fig.1). River Shivna is the tributary for river Chambal that flows from south directions. It is seasonal river and highly polluted by both municipal and industrial waste. Three different stations of the river of both upstream and downstream were selected for the present investigation and named as Station I, II and III (I Upstream –Ramghat II. Middle stream- Pashupatinath temple and Downstream –Near Railway over Bridge).

Water sampling: Regular water samples were collected in different study stations and in different seasons of the year. Sterilized pre-cleaned plastic polyethylene glass bottles were used for sample collection. The entire sampling container’s were washed and rinsed thoroughly with lake water prior to sampling. The collected surface water samples were collected from these three locations in a 2 Liter hygiene polyethylene bottles for a period of 12 months from August 2012 to July 2013. The suitability of the surface water from River Shivna at Mandsaur for drinking, domestic, and irrigation purposes was calculated by comparing the values of different water quality parameters with those of the Bureau of Indian standards (BIS) guideline values for drinking water.

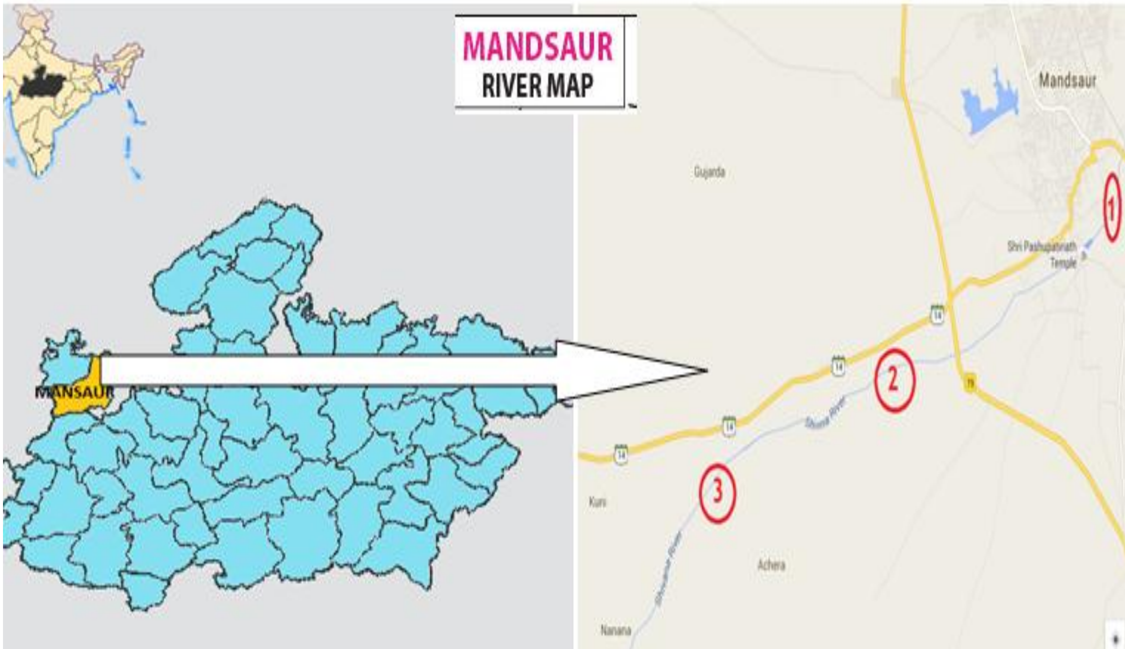

Fig.1. Map showing the study locations of Shivna River at Mandsaur, India

Calculation of WQI:WQI is described as a score that reveals the combined influence of different water quality parameters. It is of the most valuable tool to correspond information on the quality of water to the concerned general public and policy makers. The WQI provides a complete representation of the quality of surface/ground water for most domestic uses. Hence, a total of 288 water samples in three different study stations in different months of the year were collected during the period from November 2012 to October 2013. A sample of 500 ml of water was collected from each site in plastic cans and analyzed for eight physicochemical parameters. The factors like pH, temperature, Electrical conductivity (EC) and dissolved oxygen (DO) were determined at the sampling site while the parameters like alkalinity, nitrate, chloride and phosphate were analyzed in the laboratory as per the standard methods of the American Public Health Association (APHA, 1995).The water quality index (WQI) was computed by using the standards of drinking water quality recommended by the Bureau of Indian Standards (BIS, 2003) and the Indian Council of Medical Research (ICMR, 1975). The weightage for parameters is specified according to use. Each one of the water parameters were assigned a weight (w_i) based on their supposed effects on primary health and their comparative importance in the overall quality of water for drinking purposes (Table 2). The maximum weight of five was allocated to parameters which have the major effects on water quality and their significance in quality (viz, NO_3^-, F^- and TDS) and a minimum of two was allocated to parameters which are considered as not harmful (Ca^{2+}, Mg^{2+}, K^+). By computing the relative weight (W_i) of each parameter using appropriate equation Table 2 present the weight (w_i) and calculated relative weight (W_i) values for each parameter. Most significant/representative parameter for the use is given higher weightage than the less important one. The weighted average of the parameter will give the WQI of that sample for the desired purpose. The purpose will also select the choice of the parameters. Then after, a standard for maximum and minimum permissible limit is selected and calculated the average of the value. It is to be noted that the influential parameter for drinking water is given higher weightage than the others. The error due to time has been excluded.

The WQI has been computed by using the standards of drinking water quality recommended by the Bureau of Indian Standards (BIS, 2003), World Health Organization (WHO, 1985) and Indian Council for Medical Research (ICMR, 1975). The weighted arithmetic index method of Brown et. al., (1972) has been employed for the computation of WQI of the surface water of the River. Besides, quality rating or sub index (q_n) was calculated using the following expression.

$$q_n = 100[V_n - V_{io}] / [S_n - V_{io}]$$

(Let there be n water quality parameters and quality rating or sub index (q_n) corresponding to n^{th} parameter is a figure reflecting the relative value of this parameter in the polluted water with respect to its standard permissible value.)

q_n =Quality rating for the n^{th} Water quality parameter

V_n=Estimated value of the n^{th} parameter at a given sampling station.

S_n =Standard permissible value of the n^{th} parameter.

V_{io} = Ideal value of n^{th} parameter in pure water. (i.e., 0 for all other parameters except the parameter pH and Dissolved oxygen (7.0 and 14.6 mg/L respectively)

Unit weight was calculated by a value inversely proportional to the recommended standard value S_n of the corresponding parameter.

W_n =K/ S_n

W_n= unit weight for the n^{th} parameters.

S_n= Standard value for n^{th} parameters

K= Constant for proportionality.

On the whole the Water Quality Index was determined by aggregating the quality rating with the unit weight linearly.

$$WQI = \sum q_n W_n / \sum W_n$$

RESULTS AND DISCUSSION

Water quality index (WQI) is an important and unique tool to illustrate the overall water quality status and is helpful for the selection of suitable treatment technique to meet the concerned issues. In the present investigation WQI has been calculated for three sites for Shivna River at Mandsaur (Western Madhya Pradesh) in three different seasons of the year. Festivals in India are an integral part of rich and diverse cultural heritage. Worship of the Idol of God has been in the practice in India since ancient time and things like milk, curd, ghee, coconut, beetle, and river water were usually used. The city, Mandsaur is well known for its worldwide famous lord Pashupatinath temple situated on the bank of River Shivna. People from worldwide come here, worship and offer a variety of natural and synthetic products for worship and to decorate the idol which enter into the River and severely affecting the water quality. These natural and synthetic chemicals dissolve slowly leading to significant alternation in the water quality. Further, the floating materials released through the temple, industries and municipality into the river after decomposition result in eutrophication.

Table 1: Water Quality Index (WQI) and status of water quality (WHO, 1985)

Water quality Index Level	Water quality status
0-25	Excellent water quality
26-50	Good water quality
51-75	Poor water quality
76-100	Very Poor water quality
>100	Unsuitable for drinking

The water samples of River Shivna at Mandsaur in different seasons were found to be colorless and neutral. This study clearly shows that, the status of the surface water of the Shivna River is eutrophic and it is inappropriate for the human uses. It is also found that the pollution load is comparatively high during summer season when compared to other seasons. The value of the physico-chemical parameters were compared with desirable/permissible limit of ICMR/BIS of drinking water specification (BIS, 2003, ICMR, 1975). The WQI for the water samples of Shivna River at Mandsaur were ranged 96.0-171.2 Results Clear shows the WQI varies with season and segment of the River. It was found that 76% were in the "poor" category in summer, followed by 70.6% in winter and 51% in season. 54.6% of water samples were in the "good" category in rainy and 55.3% were of "very poor" quality in winter. None of the samples were in the "excellent" or "unsuitable for drinking" categories. Water quality was better in winter compared to that in summer or monsoon (Table, 4, 5, 6, 7&8).

The average temperature ranged 19.3 in winter and 36.1 in summer. The pH ranged 6.7-8.7, with mean values 6.8 ± 0.39 in monsoon, 8.3 ± 0.33 in summer, and 8.4 ± 0.35 in monsoon. The pH was observed to decline during the monsoon and increase in the winter season. 99% of the mean samples were not exceeding the BIS/ICMR limits. It is ranged between 6.2-8.6. Electrical conductivity (EC) is a measure of the potential of water to carry an electrical current. This capacity is connected to the total amount of solids dissolved in the water. Hence water with high ions content tends to have higher conductivity, which is an indicator of high solid concentration dissolved in the water. The values of water conductivity in the River Shivna varied from 310 µs/cm (upstream) to 4800 µs/cm to in the downstream. The value of conductivity was recorded lowest in Station I and maximum in Station III shows poor quality of water in the downstream of the River.

Table 2: Drinking Water standards recommending Agencies and unit weights. (All values except pH and Electrical Conductivity are in mg/l)

Sr.No.	Parameters	Standards	Recommended agency	Unit Weight
1.	pH	6.5-8.5	ICMR/BIS	**0.2190**
2.	Total alkalinity	120	ICMR	**0.0155**
3.	Chlorides	250	ICMR	**0.0074**
4.	Nitrate	45	ICMR/BIS	**0.0412**
5.	phosphate	0.05	ICMR/BIS	**0.03**
6.	Dissolved oxygen	5.00	ICMR/BIS	**0.3723**
7.	**EC.umho/cm**	**300**	**ICMR**	**0.371**

Table 3: Analytical methods adopted with the BIS desirable and Permissible limits

Sl. No.	Characteristics	Analytical method	Unit	BIS limits (1998)	
				Desirable	Permissible
1.	pH	Electrode	-	6.5-8.5	6.5-8.5
2.	Electrical conductivity (EC)	Conductivity meter	µS/cm	2,000	3,000
3.	Total dissolved solids (TDS)	Conductivity-TDS meter	mg/L	1,000	2,000
4.	Total Alkalinity (TA)	Titrimetric	mg/L	200	600
5.	Dissolved Oxygen (DO)	Modified Winder's method	mg/L	6.0	NA
6.	Chlorides (Cl^-)	Argentometric titration	mg/L	250	1,000
7.	Nitrates (as NO_3^-)	Ion selective electrode (ISE)	mg/L	45	45
8.	Phosphates (as PO_4^{3-})	Stannous chloride	mg/L	0.3	0.3

Table 4: The weight and relative weight of each of the physico-chemical parameters used for WQI determination

Parameters	BIS desirable limit (1998)	Weight (w_i)	Relative weight (W_i)
pH	8.5	3	0.0698
Electrical conductivity	2,000	3	0.0698
Total dissolved solids	1,000	5	0.1163
Total alkalinity	200	2	0.0465
Potassium	10	2	0.0465
Chloride	250	3	0.0698
Nitrate	45	5	0.1163
	-	$\Sigma w_i = 43$	$\Sigma W_i = 1.000$

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Table.5: Seasonal variations of the physicochemical parameters of the surface water of Shivna River at Mandsaur

Sr.No.	Parameters	Rainy season			Winter Season			Summer season		
	Study Stations →	S1	S2	S3	S1	S2	S3	S1	S2	S3
1.	pH	6.8	6.9	7.0	7.8	8.1	8.4	8.2	8.7	8.6
2.	Electrical Conductivity	380	290	302	395	389	395	401	412	426
3.	Total Dissolved Solids	575	587	581	356	452	462	390	587	535
4.	Total alkalinity	58	62	70	75	81	85	51	69	73
5.	Chlorides	24.74	25.22	26.51	24.14	27.21	23.51	26.72	24.11	28.17
6.	Nitrate	0.201	0.191	0.166	0.31	0.21	0.186	0.231	0.21	0.26
7.	Dissolved oxygen	6.9	7.1	7.4	8.3	8.6	8.8	7	8.7	8.6
8.	EC,umho/cm	85.73	321.2	321.2	85.73	321.2	321.2	85.73	321.2	321.2
	Water Quality Index	96.00			101.7			106.3		

Table.6:Water Quality index in of Shivna River in Rainy season at Mandsaur

Sr.No.	Parameters	Observed values	Standard Values(S_n)	Unit Weight (Wn)	Quality rating(q_n)	W_nq_n
1.	pH	7.2	6.5-8.5	0.2190	13.33	2.92
2.	Electrical Conductivity	310	300	0.371	126.67	46.99
3.	Total Dissolved Solids	575	500	0.0037	115.00	0.43
4.	Total alkalinity	158	120	0.0155	48.33	0.75
5.	Chlorides	156	250	0.0074	62.33	0.46
6.	Nitrate	42	45	0.0412	93.33	3.85
7.	Dissolved oxygen	7.5	5.00	0.3723	80.00	29.78
8.	EC,umho/cm	18	5.00	0.3723	133.33	49.64
				$\sum Wn$ =1.51	**$\sum q_n$** =1090.73	**$\sum W_nq_n$** =145.04

Water Quality Index $=\sum q_n Wn/\sum Wn$ = 96.00

Table.7:Water Quality index of Shivna River in winter season at Mandsaur

Sr.No.	Parameters	Observed values	Standard Values(S_n)	Unit Weight (Wn)	Quality rating(q_n)	W_nq_n
1.	pH	8.2	6.5-8.5	0.2190	13.33	2.92
2.	Electrical Conductivity	399	300	0.371	126.67	46.99
3.	Total Dissolved Solids	584	500	0.0037	115.00	0.43
4.	Total alkalinity	176	120	0.0155	48.33	0.75
5.	Chlorides	210	250	0.0074	62.33	0.46
6.	Nitrate	49	45	0.0412	93.33	3.85
7.	Dissolved oxygen	6.4	5.00	0.3723	80.00	29.78
8.	EC,umho/cm	21	5.00	0.3723	133.33	49.64
				$\sum Wn$ =1.51	**$\sum q_n$** =1168.9	**$\sum W_nq_n$** =158.2

Water Quality index= WQI$=\sum q\ n\ Wn/\sum Wn = 110.2$

Table.8:Water Quality index of Shivna River in Summer season at Mandsaur

Sr.No.	Parameters	Observed values	Standard Values(S_n)	Unit Weight (Wn)	Quality rating(q_n)	W_nq_n
1.	pH	8.6	6.5-8.5	0.2190	13.33	2.92
2.	Electrical Conductivity	480	300	0.371	126.67	46.99
3.	Total Dissolved Solids	596	500	0.0037	115.00	0.43
4.	Total alkalinity	158	120	0.0155	48.33	0.75
5.	Chlorides	176	250	0.0074	62.33	0.46
6.	Nitrate	68	45	0.0412	93.33	3.85
7.	Dissolved oxygen	6.2	5.00	0.3723	80.00	29.78
8.	EC,umho/cm	31	5.00	0.3723	133.33	49.64
				$\sum$**Wn** =1.51	$\sum$**q_n** =1241.2	$\sum$**W_nq_n** =171.2

The chloride reaches the river from different anthropogenic activities like septic tank effluents and animal feeds. Elevated concentration of chloride can make water distasteful and therefore unsuitable for drinking or livestock watering. The chloride concentration fluctuated in the range of 20-29 mg/l, with mean values 18.31 ± 5.27 in winter, 29.35 ± 6.79 in summer, and 23.44 ± 6.24 in monsoon. But the concentration of chloride was found to be within permissible limits. DO varied in the range of 6.1-8.1 mg/l, with mean values 8.02 ± 1.38 in winter, 6.13 ± 1.09 in summer and 6.72 ± 1.42 in monsoon. Each and every one the parameters in all seasons and in all study stations significantly differed statistically ($P < 0.01$) from the standard values. The water was found to be muddier during the monsoon and summer seasons compared to the winter season which may be due to soil erosion, water discharge, agricultural runoff, etc. In the same way, many other investigators in reported high turbidity in summer and monsoon compared to winter (Reddy and Baghel, 2010, Reddy,2012[a,b], Parmar and Reddy,2013).

Chloride is one of the most significant factor in assessing the water quality. The presence of higher concentrations of chlorides in surface water indicates higher degree of organic pollution (Munawar, 1970). But in the present study the concentration of chloride oscillated between 156 mg/1 and 178 mg/1and found to be high during summer season. The concentration of dissolved oxygen (DO) normalizes the distribution of flora and fauna. The results in the present investigation point out that the concentration of dissolved oxygen fluctuated between 6.4ml/1 and 8.6ml/1. Like other parameters the concentration of dissolved oxygen was more during monsoon and least during summer. This observation is in agreement with the observations of some other studies (Kotadiya, et al, 2013). The mean values of WQI for all the sampling sites in the different seasons, that is, winter, summer, and monsoon are 55.17 ± 9.98, 66.77 ± 10.34, and 68.29 ± 11.5 respectively, which indicates poor quality of water. Most of the samples, that is, 76% showed poor quality of water in summer. Few other studies based on WQI for untreated natural water conducted in India have also reported poor quality of water in summer and monsoon compared to the winter season (Thakor, et al, 2011, Kotadiya, et al, 2013).

In this study, the calculated WQI values have a range from 96.66 to 171.08 and thus can be categorized into three water types, excellent water to unsuitable water for drinking. Minimum is 96.66 at site I while maximum value was 171.08 at site III. There is no single site's water quality can be expressed as excellent but the water quality of site I (Upstream) can be classified as good water.

CONCLUSIONS

The WQI method is more methodical and facilitates the comparative evaluation of water quality of several sampling sites. The WQI values of current study revealed that the status of water quality is not appropriate for drinking purposes, and therefore prior treatment is required before use. It is advocated that more investigations to be carried out covering more areas and to spread public health education. The outcome of this study is expected to be a supportive tool for the public and for water quality management.

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