

Experimental Study of Water Quality Parameters of the Narmada River at Bargi Dam, Jabalpur

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Research Article

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Abstract

The Narmada River, regarded as one of the most sacred rivers of India, is the third holiest and the seventh longest among the country's major river basins. It originates in the Amarkantak hills of the Mekala range in Shahdol district, Madhya Pradesh, and serves as a principal source of domestic water supply and irrigation for the surrounding region. The present study evaluates the influence of Bargi Dam on the physicochemical quality of Narmada River water along the Jabalpur–Mandla stretch. Water samples were collected from fifteen locations – five sites in the Mandla region and ten sites in the Jabalpur region – representing three zones: immediately upstream of the dam (X-1), the dam basin (X-2), and immediately downstream of the dam (X-3). Samples were analysed at the Public Health Engineering (P.H.E.) Vijay Nagar Laboratory, Jabalpur, for ten physicochemical parameters, namely pH, turbidity, electrical conductivity, total hardness, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, chloride content, alkalinity and acidity. A Water Quality Index (WQI) was computed for each zone using the weighted arithmetic index method, referenced against WHO, BIS (IS:10500) and ICMR drinking-water standards. The WQI was found to be 67.77 at X-1, 59.15 at X-2 and 56.86 at X-3, indicating a progressive improvement of about 16.1% in water quality from upstream to downstream of the dam. All measured parameters remained within permissible limits at every site, though the overall WQI classified the water as “poor” at all three zones. The findings indicate that Bargi Dam has a beneficial regulating effect on downstream water quality and highlight the need for periodic monitoring and eco-friendly management of ghats and waste disposal along the river.

INTRODUCTION

Water is one of the primary necessities for the growth and activity of all living organisms on Earth. Although nearly 71% of the Earth's surface is covered by water, only about 3% is fresh, and of this, roughly 75% is locked in glaciers and polar ice, 24% exists as groundwater, and barely 1% is available as usable fresh water in rivers, lakes and ponds (Dugan, 1972). Rising industrialisation and population growth have placed increasing demand on this limited resource, while a large share of the available fresh water is contaminated with sewage, industrial effluent and synthetic chemicals. According to the National Environmental Engineering Research Institute, Nagpur, nearly 70% of the water available in India is polluted (Pani, 1986). Water quality testing is therefore one of the most important aspects of surface water research, and the water quality index (WQI) is widely used as a single score reflecting the composite influence of multiple water quality parameters on overall water quality.

The Narmada river basin lies in central India between 72°32'E–81°45'E and 21°20'N–23°45'N, draining an area of about 98,796 km² at an average elevation of 760 m. The river has a total length of 1,312 km, with its catchment spread across Madhya Pradesh (86.18%), Gujarat (11.6%), Maharashtra (1.5%) and Chhattisgarh (0.72%). Jabalpur, located at approximately 23°10'N, 79°57'E at an average elevation of 411 m above sea level, draws its principal domestic and irrigation water supply from the Narmada. The river is also considered the third holiest and seventh longest of India's major rivers, and large numbers of people gather at its ghats for religious bathing, idol immersion (visarjan) and other rituals, all of which contribute organic and inorganic pollutant loads to the river.

Several studies have examined the physicochemical status of the Narmada and other Indian rivers in relation to religious and anthropogenic activity. Shukla and Patel (2015) reported that despite being among the cleanest rivers in India, the Narmada faces water-quality threats from the disposal of worship remains (nirmalya) and sewage, and recommended dedicated puja ghats to manage this load. Chourasiya and Karan (2015) found that faecal coliform counts, dissolved oxygen, BOD and COD in the Mandakini River were significantly altered by collective bathing during Amavasya. Mehta (2014) observed marked increases in TSS, TDS, conductivity, hardness, DO, BOD and COD in lakes at Jodhpur during and after idol immersion. Sharma and Joshi (2014) analysed the strengths, weaknesses and threats of pilgrimage tourism at Haridwar and noted adverse socio-environmental impacts of the Kanwar Mela. Soni and Visavadia (2013) studied the western stretch of the Narmada and reported seasonal deterioration in water quality with elevated chloride and reduced dissolved oxygen. Sharma et al. (2011) and Telang et al. (2009) both linked increased pilgrim and tourist activity at Haridwar and Hoshangabad to elevated levels of BOD, COD and faecal contamination, while Saini et al. (2009) associated poor sanitation during the Kanwar Mela with a rise in water- and air-borne disease. Basant Rai (2013) further linked high BOD levels in the Ganga to outbreaks of dysentery, cholera, hepatitis and diarrhoea. Collectively, these studies underline the need for continuous monitoring of physicochemical water quality on rivers subject to intense religious and anthropogenic pressure.

The present study was undertaken to evaluate the impact of the Bargi Dam on the water quality of the Narmada River in the Bargi basin region. The specific objectives of the study were:

- to conduct field visits and surveys of the raw water bodies at various locations;
- to collect water samples from fifteen selected locations (five in the Mandla region and ten in the Jabalpur region);
- to determine the physicochemical parameters of the water samples – pH, turbidity, electrical conductivity, total hardness, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, chloride content, alkalinity and acidity;
- to assess the spatial variation in water quality upstream, within, and downstream of Bargi Dam through the Water Quality Index; and
- to suggest sustainable strategies for water quality management following construction of the Bargi Dam on the Narmada River.

The study is confined to the Narmada River in the Mandla and Jabalpur districts and focuses on the changes in the Water Quality Index and individual physicochemical parameters associated with the Bargi Dam. The findings are intended to support the development of effective water-resource management strategies and public guidelines for the sustainable use of the river.

MATERIALS AND METHODS

Study Area and Sampling Sites

Fifteen sampling locations were selected along the Narmada River in the Bargi basin, comprising five sites in the Mandla region and ten sites in the Jabalpur region. For analysis, the sites were grouped into three zones:

Zone X-1, immediately upstream of Bargi Dam (samples S-1 to S-5); Zone X-2, the basin water of Bargi Dam (samples S-6 to S-10); and Zone X-3, immediately downstream of Bargi Dam (samples S-11 to S-15).

Sample Collection

Water samples were collected in 300 mL and 1.0 L plastic bottles fitted with caps. Each bottle was washed with 2% nitric acid and rinsed three times with distilled water before use, and stored in a clean environment prior to sampling. Bottles were filled without headspace and sealed immediately to prevent leakage or aeration, and each container was labelled with the date and location of sampling. Samples were transported to and analysed at the Pollution Control Board's laboratory, P.H.E. Vijay Nagar Laboratory, Jabalpur, for pH, turbidity, electrical conductivity, total hardness, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, chloride content, alkalinity and acidity.

Analytical Methods

pH was measured electrometrically using a calibrated pH meter, standardised against buffer solutions bracketing the sample pH; the electrode was rinsed and equilibrated in the sample before a stable reading (drift < 0.1 pH unit) was recorded.

Turbidity was determined nephelometrically, based on light scattering by suspended particles in the sample.

Electrical conductivity, the reciprocal of resistance, was measured with a conductivity meter comprising an alternating-current source, a Wheatstone-bridge null indicator and a conductivity cell, and expressed in $\mu\text{S}/\text{cm}$ at 25°C.

Total hardness was determined by EDTA titrimetry. A standard EDTA solution was prepared by dissolving 3.723 g of EDTA in demineralised water and diluting to 1000 mL. A 25.0 mL aliquot of sample was buffered, a few drops of Eriochrome Black-T indicator were added, and the solution was titrated slowly with standard EDTA until the colour changed from wine-red to sky-blue. Total hardness was calculated as: Total Hardness (mg/L) = (Burette reading $\times$ 0.01 $\times$ 50000) / volume of sample (mL).

Dissolved oxygen (D.O.) was determined by the Winkler (azide modification) method. Manganese sulphate and alkali-iodide-azide reagents were added to a 300 mL BOD bottle of sample to fix the oxygen as a manganese hydroxide floc; concentrated sulphuric acid was then added to dissolve the floc and liberate iodine equivalent to the dissolved oxygen present. A 200 mL aliquot was titrated against standard sodium thiosulphate (0.025 N) to a pale-straw colour, starch indicator was added, and titration was continued to the disappearance of the blue colour, the titre value being taken as the D.O. concentration.

Biochemical oxygen demand (BOD) was determined as the difference between the initial dissolved oxygen and the dissolved oxygen remaining after 5 days' incubation at 20°C in the dark: BOD (mg/L) = Initial D.O. – Final D.O.

Chemical oxygen demand (COD) was determined by the closed-reflux dichromate digestion method using a COD digester, potassium dichromate, sulphuric acid, silver sulphate and mercury sulphate, with the excess

dichromate back-titrated against standard ferrous ammonium sulphate using ferroin indicator: COD (mg/L) = (Burette reading × 0.25 × 8000) / volume of sample (mL).

Chloride content was determined by mercurimetric titration, exploiting the formation of soluble, slightly dissociated mercuric chloride; diphenylcarbazone indicator, in the pH range 2.3–2.8, marked the end point by formation of a purple mercury complex. Samples were titrated with standard mercuric nitrate (0.141 N): Chloride (mg/L) = (Burette reading × 5 × 0.0141) / volume of sample (mL).

Alkalinity and acidity were determined by acid–base titration using phenolphthalein indicator (colour change at pH 8.3) and methyl orange indicator (colour change at pH 4.5), respectively.

Table A. Permissible limits of the physicochemical parameters analysed (IS: 10500–1983 and WHO, 1985)

Parameter	IS: 10500–1983	WHO (1985)
pH	6.5 – 8.5	6.5 – 8.5
Turbidity (NTU)	10 (max. desirable)	5
Total Hardness (mg/L)	300	500
Chloride (mg/L)	250	250 (as Cl)

Water Quality Index (WQI)

The Water Quality Index was computed using the weighted arithmetic index method (Brown et al.), based on ten physicochemical parameters and referenced against the drinking-water standards of the World Health Organization (WHO), the Bureau of Indian Standards (BIS) and the Indian Council of Medical Research (ICMR). The quality rating (sub-index) for each parameter was calculated as:

$Q_i = 100 \times [(V_n - V_i) / (V_s - V_i)]$

where V_n is the observed value of the n th parameter, V_i is the ideal value of the parameter ($V_i = 0$ for all parameters except pH, for which $V_i = 7.0$, and dissolved oxygen, for which $V_i = 14.6$ mg/L), and V_s is the recommended WHO standard for the parameter. The relative unit weight (W_i) of each parameter was taken as inversely proportional to its recommended standard (S_i): $W_i = 1/S_i$. The overall Water Quality Index was then computed as:

$WQI = \Sigma(Q_i \times W_i) / \Sigma W_i$

For this study, the WQI was computed independently for each of the three sampling zones (X-1, X-2 and X-3), permissible WQI for drinking water being taken as 100, with the classification scheme shown in Table 4.

Table 4. Water quality classification based on WQI value

WQI Range	Quality of Water
0 – 24	Excellent
25 – 49	Good
50 – 75	Poor
75 – 100	Very Poor
> 100	Unfit for Drinking

RESULTS

The physicochemical parameters measured at the fifteen sampling locations, grouped into the three study zones, are presented in Tables 1–3.

Table 1. Physicochemical parameters at Zone X-1 (immediately upstream of Bargi Dam)

S. No.	Physicochemical Parameter	Unit	X-1 (Just Upstream of Bargi Dam)					Composite Sample Value	Standard Value
			S-1	S-2	S-3	S-4	S-5		
1	pH	-	7.37	7.41	7.42	7.39	7.37	7.29	6.5-8.5
2	Turbidity	NTU	9.8	9.6	9.3	9.9	9.1	9.5	5-10
3	Conductivity	μS/cm	163.7	163.2	165.5	164.7	167.1	163.3	750
4	Total Hardness	mg/L	110	106	109	110	124	114	300
5	Dissolved Oxygen	mg/L	7.9	8.1	8	8.2	7.9	7.9	Min. 5
6	B.O.D.	mg/L	1.7	1.5	1.4	1.6	1.2	1.7	Max. 3
7	C.O.D.	mg/L	8	10	8	8	10	9	200
8	Chloride	mg/L	25	23	27	30	32	23	250
9	Alkalinity	mg/L	95	94	98	91	90	97	200
10	Acidity	mg/L	112	127	115	107	114	117	200

Table 2. Physicochemical parameters at Zone X-2 (basin water of Bargi Dam)

S. No.	Physicochemical Parameter	Unit	X-2 (Basin Water of Bargi Dam)					Composite Sample Value	Standard Value
			S-6	S-7	S-8	S-9	S-10		
1	pH	-	7.36	7.33	7.36	7.21	7.29	7.31	6.5-8.5
2	Turbidity	NTU	5.3	5.7	5.9	5.4	5.2	6	5-10
3	Conductivity	μS/cm	165.4	164.2	163.7	166.2	165.1	164.7	750
4	Total Hardness	mg/L	88	84	90	94	98	96	300
5	Dissolved Oxygen	mg/L	7.8	7.7	7.9	7.7	7.8	7.6	Min. 5
6	B.O.D.	mg/L	1.8	1.6	1.5	1.7	1.4	1.5	Max. 3
7	C.O.D.	mg/L	14	12	15	15	10	13	200
8	Chloride	mg/L	32	31	35	37	40	33	250
9	Alkalinity	mg/L	73	72	75	74	79	81	200
10	Acidity	mg/L	107	110	105	100	90	95	200

Table 3. Physicochemical parameters at Zone X-3 (immediately downstream of Bargi Dam)

S. No.	Physicochemical Parameter	Unit	X-3 (Just Downstream of Bargi Dam)					Composite Sample Value	Standard Value
			S-11	S-12	S-13	S-14	S-15		
1	pH	-	7.42	7.41	7.39	7.21	7.31	7.4	6.5-8.5
2	Turbidity	NTU	5.2	5.9	5.4	5.1	5.3	5.3	5-10
3	Conductivity	μS/cm	147	159	153.3	158	159.4	158.6	750
4	Total Hardness	mg/L	85	85	80	93	81	88	300
5	Dissolved Oxygen	mg/L	8.5	7.8	7.7	8.6	7.8	8	Min. 5
6	B.O.D.	mg/L	1	1.7	1.8	1	1.6	1.3	Max. 3
7	C.O.D.	mg/L	19	8	10	12	8	19	200
8	Chloride	mg/L	27	22	29	25	29	29	250
9	Alkalinity	mg/L	62	65	63	87	62	69	200
10	Acidity	mg/L	80	82	85	87	80	80	200

At all three zones, every measured parameter remained within the permissible limits prescribed by IS:10500–1983 and WHO (1985). pH ranged from 7.21 to 7.42 across all sites, well within the 6.5–8.5 limit. Turbidity was highest at X-1 (9.1–9.9 NTU) and lower at X-2 and X-3 (5.1–5.9 NTU), while conductivity, hardness, chloride, alkalinity and acidity were all comfortably below their respective standards at every site. Dissolved oxygen remained above the minimum requirement of 5 mg/L (7.6–8.6 mg/L), and BOD and COD stayed well below their maximum permissible values of 3 mg/L and 200 mg/L respectively at all zones.

The Water Quality Index computed for each zone using the weighted arithmetic index method is presented in Tables 5–7.

Table 5. Calculation of Water Quality Index for Zone X-1 (just upstream of Bargi Dam)

S. No.	Parameter	Composite Sample Value (Vn)	Standard Value (Si)	Unit Weight (Wi)	Quality Rating (Qi)	(Wi × Qi)/ ΣWi
1	pH	7.29	6.5-8.5	0.133	58	9.08
2	Turbidity	9.5	5-10	0.133	126.67	19.68
3	Conductivity	163.3	750	0.0013	21.77	0.033
4	Total Hardness	114	300	0.003	38	0.133
5	Dissolved Oxygen	7.9	Min. 5	0.2	69.79	16.31
6	B.O.D.	1.7	Max. 3	0.33	56.67	21.84
7	C.O.D.	9	200	0.005	4.5	0.03
8	Chloride	23	250	0.004	9.2	0.0429
9	Alkalinity	97	200	0.005	48.5	0.283
10	Acidity	117	200	0.005	58.5	0.341
				ΣWi = 0.856	WQI	67.7729

Table 6. Calculation of Water Quality Index for Zone X-2 (basin water of Bargi Dam)

S. No.	Parameter	Composite Sample Value (Vn)	Standard Value (Si)	Unit Weight (Wi)	Quality Rating (Qi)	(Wi × Qi)/ ΣWi
1	pH	7.31	6.5-8.5	0.133	62	9.633
2	Turbidity	6	5-10	0.133	80	12.43
3	Conductivity	164.7	750	0.0013	21.96	0.0334
4	Total Hardness	96	300	0.003	32	0.112
5	Dissolved Oxygen	7.6	Min. 5	0.2	72.92	17.04
6	B.O.D.	1.5	Max. 3	0.33	50	19.28
7	C.O.D.	13	200	0.005	6.5	0.038
8	Chloride	33	250	0.004	13.2	0.061
9	Alkalinity	81	200	0.005	40.5	0.24
10	Acidity	95	200	0.005	47.5	0.278
				ΣWi = 0.856	WQI	59.1454

Table 7. Calculation of Water Quality Index for Zone X-3 (just downstream of Bargi Dam)

S. No.	Parameter	Composite Sample Value (Vn)	Standard Value (Si)	Unit Weight (Wi)	Quality Rating (Qi)	(Wi × Qi)/ ΣWi
1	pH	7.4	6.5-8.5	0.133	80	12.43
2	Turbidity	5.3	5-10	0.133	70.67	10.98
3	Conductivity	158.6	750	0.0013	21.15	0.032
4	Total Hardness	88	300	0.003	29.34	0.103
5	Dissolved Oxygen	8	Min. 5	0.2	68.75	16.06
6	B.O.D.	1.3	Max. 3	0.33	43.34	16.71
7	C.O.D.	19	200	0.005	9.5	0.056
8	Chloride	29	250	0.004	11.6	0.054
9	Alkalinity	69	200	0.005	34.5	0.2
10	Acidity	80	200	0.005	40	0.234
				ΣWi = 0.856	WQI	56.859

The computed WQI was 67.77 at Zone X-1 (just upstream of Bargi Dam), 59.15 at Zone X-2 (basin water of Bargi Dam) and 56.86 at Zone X-3 (just downstream of Bargi Dam), a reduction of approximately 16.1% from X-1 to X-3.

DISCUSSION

Although every individual physicochemical parameter remained within the permissible limits of IS:10500 and WHO (1985) at all three zones, the composite Water Quality Index classified the water at all three zones as “poor” (WQI 50–75) as per the classification scheme in Table 4. This illustrates the value of a composite index over single-parameter assessment: while no individual determinant exceeded its standard, the cumulative influence of several parameters, weighted by their relative significance, indicated a water quality that is usable but requires treatment before direct consumption.

The consistent decline in WQI from X-1 (67.77) to X-2 (59.15) and X-3 (56.86) suggests that the dam exerts a net purifying influence as water passes from just upstream of the structure, through the basin, to just downstream. This is broadly consistent with reductions observed in turbidity (from a mean of about 9.5 NTU at X-1 to about 5.3–6.0 NTU at X-2 and X-3) and with the moderation of hardness, alkalinity, acidity and chloride at the downstream zones, likely aided by settling of suspended solids and dilution/retention effects within the reservoir. The improvement is broadly consistent with earlier reports that dam-regulated stretches show more stable water quality than free-flowing, heavily used stretches subject to intense religious and anthropogenic loading, as documented for other Indian rivers by Chourasiya and Karan (2015), Mehta (2014) and Telang et al. (2009).

Dissolved oxygen remained adequate (> 7.5 mg/L) at all zones, and BOD/COD values were well within permissible limits, indicating that the organic pollution load in this stretch of the Narmada is currently moderate. Nonetheless, given that religious bathing, idol immersion and disposal of offerings are common along this stretch, continued vigilance is warranted, since even the parameters within limits at present could deteriorate if anthropogenic loading increases, as has been observed on other Indian rivers subject to similar religious and tourist pressure (Sharma and Joshi, 2014; Sharma et al., 2011; Saini et al., 2009).

CONCLUSION

Fifteen water samples were collected from the Narmada River at Bargi Dam and analysed for ten physicochemical parameters at the Pollution Control Board's laboratory, Jabalpur. The findings show that all measured parameters – pH, turbidity, conductivity, total hardness, dissolved oxygen, BOD, COD, chloride, alkalinity and acidity – remained within the permissible limits prescribed by IS:10500–1983 and WHO (1985) at all three study zones. The Water Quality Index was 67.77 at Zone X-1 (just upstream of Bargi Dam), 59.15 at Zone X-2 (basin water of Bargi Dam) and 56.86 at Zone X-3 (just downstream of Bargi Dam), a reduction of about 16.1% from upstream to downstream. This indicates that construction of the Bargi Dam has had a beneficial, regulating effect on the water quality of the Narmada River in this stretch, even though the composite WQI classifies the water as “poor” and therefore not suitable for direct drinking-water use without treatment.

Based on these findings, the following measures are recommended for sustainable management of water quality in this stretch of the Narmada River:

- Development of dedicated, eco-friendly visarjan ghats/kunds, separated from the main river flow and equipped with adequate pumping and filtration arrangements, for idol immersion and religious offerings.
- Public awareness campaigns – through signage, posters, print and electronic media – to discourage the disposal of waste into the river.
- Regular water-quality monitoring, at least three to four times a month, to track variation in physicochemical parameters and detect pollution promptly.
- Formulation of strategies to minimise the negative impacts of religious tourism and to promote eco-tourism along the river.
- Development of comprehensive social, religious, scientific and environmental guidelines to support sustainable management of the river's water resources, in terms of both quantity and quality.

Future work could extend this monitoring approach to additional dams and barrages on the Narmada and other rivers, to evaluate their role in controlling pollution and improving downstream water quality on a larger scale.

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