International Journal of Academic Research and Development
www.allreviewjournal.com
ISSN: 2455-4197
Received: 27-10-2025, Accepted: 26-11-2025, Published: 11-12-2025
Volume 10, Issue 6, 2025, Page No. 61-68

Assessment of surface water quality and pollution status of Narmada River in Madhya Pradesh, India

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DOI: https://doi.org/10.66856/academic.2025.10.6.11075

Abstract
Rivers are essential freshwater resources that support ecological balance, biodiversity, and various human activities such as drinking, irrigation, and fisheries. However, increasing urbanization, agricultural practices, and human settlements have raised concerns about the deterioration of river water quality. The present study was carried out to assess the physico-chemical and bacteriological characteristics of the upper stretch of the Narmada River from its origin at Amarkantak to Dindori district in Madhya Pradesh, India. Six sampling locations were selected along the river course, namely Narmada Kund (origin), Pushkar Dam, Kapil Dhara, Chandan Ghat, Dindori upstream, and Dindori downstream, representing different environmental and human activity conditions.
Water samples were collected seasonally during the pre-monsoon (April–June 2025) and monsoon (July–September 2025) periods. The samples were analyzed using standard procedures recommended by APHA (2017) to determine key physico-chemical parameters including temperature, pH, total alkalinity, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total hardness, nitrate, phosphate, chloride, and sulphate. Bacteriological analysis was conducted to estimate total coliform and fecal coliform using the Most Probable Number (MPN) method.
The results indicated slight seasonal and spatial variations in water quality parameters. Temperature and pH values remained relatively stable, indicating a favourable environment for aquatic organisms. Dissolved oxygen levels suggested good aeration and healthy ecological conditions. BOD and COD values indicated low to moderate organic pollution, while TDS and hardness values were within acceptable limits. Nutrient concentrations such as nitrate and phosphate were low, suggesting minimal risk of eutrophication. However, higher values of TDS, BOD, COD, and coliform bacteria were observed at downstream locations, particularly during the monsoon season, which may be attributed to surface runoff and local human activities.
Overall, the findings suggest that the upper stretch of the Narmada River maintains generally good water quality, although localized pollution was observed at certain downstream sites. Continuous monitoring and proper management practices are necessary to maintain the ecological health of the river and ensure its sustainable use in the future.

Keywords: Narmada River, water quality assessment, physico-chemical parameters, bacteriological analysis, seasonal variation, river pollution

Introduction

Rivers constitute one of the most important freshwater resources and play a crucial role in sustaining ecological balance, supporting biodiversity, and fulfilling domestic, agricultural, and industrial water demands. However, rapid urbanization, industrialization, and agricultural intensification have significantly deteriorated river water quality worldwide through the discharge of untreated domestic sewage, industrial effluents, and agricultural runoff (Ongley, 1998; Khatri & Tyagi, 2015) [2]. These anthropogenic activities alter the physico-chemical and biological characteristics of aquatic ecosystems, thereby affecting both human health and aquatic biodiversity.
The Narmada River is one of the major west-flowing rivers of peninsular India and holds significant ecological, cultural, and economic importance. It originates from Amarkantak plateau in Madhya Pradesh and flows through Madhya Pradesh, Maharashtra, and Gujarat before draining into the Gulf of Cambay. The river has a total length of approximately 1312 km and serves as a primary source of drinking water, irrigation, hydroelectric power generation, and fisheries. Despite its importance, increasing anthropogenic activities along its course have raised concerns regarding water quality degradation.
Assessment of physico-chemical parameters such as temperature, pH, dissolved oxygen, biological oxygen demand, and nutrient concentration provides reliable information about water quality status and pollution levels in river systems. Similarly, bacteriological indicators, particularly total and fecal coliform bacteria, serve as important markers of microbial contamination and public health risk. Regular monitoring of these parameters is therefore essential for effective water quality management and conservation of riverine ecosystems.
Although several studies have reported water quality characteristics of the Narmada River in different regions, limited information is available regarding the combined physico-chemical and bacteriological assessment of the river from its origin to the Dindori region. This upstream stretch is ecologically sensitive and vulnerable to increasing anthropogenic pressure from religious activities, tourism, and local settlements.
Therefore, the present study aims to evaluate the physico-chemical and bacteriological characteristics of the Narmada

River from its origin to Dindori district in Madhya Pradesh. The study seeks to assess spatial variations in water quality parameters, identify potential sources of contamination, and determine the suitability of river water for domestic and ecological purposes. The findings provide baseline data for future monitoring and contribute to sustainable river management strategies.

Materials and Methods

The present investigation was conducted along the upper stretch of the Narmada River from its origin at Amarkantak to Dindori district, Madhya Pradesh, India. The Narmada River originates from the Maikal ranges at an elevation of approximately 1057 m above sea level and flows westward across central India. Six sampling stations representing different ecological and anthropogenic conditions were selected: (i) origin point (Narmada Kund), (ii) Pushkar Dam, (iii) Kapil Dhara, (iv) Chandan Ghat, (v) Dindori upstream, and (vi) Dindori downstream. These locations were chosen to evaluate spatial variation in water quality and assess the influence of human activities along the river stretch.

Sample Collection

Water samples were collected seasonally from April 2025 to September 2025, covering pre-monsoon (April–June) and monsoon (July–September) periods. Sampling was carried out following standard procedures recommended by the American Public Health Association (APHA, 2017) [5]. Surface water samples were collected in pre-cleaned polyethylene bottles from approximately 20–30 cm below the water surface to avoid surface contamination. Samples for dissolved oxygen (DO) analysis were fixed at the sampling site using Winkler's reagents. For bacteriological analysis, sterile glass bottles were used and samples were transported to the laboratory in ice boxes and analyzed within 24 hours. All analyses were performed in triplicate, and the mean values were calculated to ensure accuracy and reliability.

Physico-Chemical Analysis

The collected water samples were analyzed for various physico-chemical parameters using standard analytical methods. The parameters analyzed included:

- **Temperature (°C):** Measured in situ using a calibrated thermometer.
- **pH:** Determined using a digital pH meter.
- **Total Alkalinity (mg/L):** Estimated by titrimetric method.
- **Dissolved Oxygen (DO, mg/L):** Determined by Winkler's method.
- **Biological Oxygen Demand (BOD, mg/L):** Measured after 5-day incubation at 20°C.
- **Chemical Oxygen Demand (COD, mg/L):** Determined by dichromate reflux method.
- **Total Dissolved Solids (TDS, mg/L):** Measured using gravimetric method.
- **Total Hardness (TH, mg/L):** Estimated by EDTA titrimetric method.
- **Nitrate (mg/L):** Determined by spectrophotometric method.
- **Phosphate (mg/L):** Estimated using stannous chloride method.
- **Chloride (mg/L):** Determined by argentometric titration.
- **Sulphate (mg/L):** Measured using turbidimetric method.
- **Total Kjeldahl Nitrogen (TKN):** Determined using Kjeldahl digestion method.

All methods followed standard procedures outlined in APHA (2017) [5].

Bacteriological Analysis

Bacteriological examination of water samples was conducted to determine total coliform and fecal coliform counts using the Most Probable Number (MPN) technique. The presence of coliform bacteria was used as an indicator of microbial contamination and sanitary quality of water.

Data Analysis and Interpretation

The obtained results were compared with permissible limits recommended by Bureau of Indian Standards (BIS 10500) and World Health Organization (WHO) guidelines for drinking water quality. Seasonal and spatial variations in physico-chemical and bacteriological parameters were analyzed to assess the overall water quality status and pollution level of the river.

Observation

The observations of physico-chemical and bacteriological parameters of river water revealed noticeable spatial and seasonal variations across the selected sampling stations from origin to Dindori. The water temperature and pH remained relatively stable throughout the study period, indicating a favourable aquatic environment. Dissolved oxygen levels were high at upstream locations, reflecting good water quality and low organic load. However, moderate increases in BOD, COD, total dissolved solids, and coliform counts were observed at downstream stations, particularly during the monsoon season, suggesting the influence of surface runoff and anthropogenic activities. Nutrient concentrations, including nitrate and phosphate, were recorded within permissible limits, indicating minimal eutrophication risk. Overall, the observations suggest that the river maintains good ecological condition with localized pollution pressure in downstream regions.

Table 1: Average value of April-June 2025

S. no	characteristics	Units	Narmada at origin point	Narmada at Puskar dam	Narmada at kapil dhara	Narmada at Chandan ghat	Narmada at Dindori up stream	Narmada at Dindori down stream
1	Temperature	^{0}C	28	28.2	27.8	28.1	28.2	28
2	pH	pH unit	7.15	7.81	7.34	7.5	7.81	7.86
3	Alkalinity	Mg/l	40	44	44	48	52	56
4	DO	Mg/l	6.3	6.5	6.8	7.2	7.7	7.8
5	COD	Mg/l	2.4	7.2	4.8	2.4	2.5	7.2

6	BOD	Mg/l	0.2	1.8	1.5	1.2	1.5	1.9
7	TDS	Mg/l	168	198	210	221	215	228
8	TH	Mg/l	104	120	122	118	124	130
9	10	Mg/l	0.16	0.24	0.2	0.18	0.16	0.2
	Phosphate	Mg/l	BDL	0.01	0.01	0.004	0.01	0.02
11	Chloride	Mg/l	24.5	29.5	24.5	19.5	19.5	24.5
12	Sulphate	Mg/l	10	11	12	10	12	13
13	T. coliform	MPN/10	3.7	70	70	50	47	70
14	F. coliform	MPN/10	<1.8	1.8	<1.8	<1.8	<1.8	1.8
15	total kjeldahl nitrogen	Mg/l	-	-	-	-	-	-

Table 2: Average Value of July-September 2025

S. no	Characteristic	Units	Narmada at origin point	Narmada at Puskar dam	Narmada at kapil dhara	Narmada at Chandan ghat	Narmada at Dindori up stream	Narmada at Dindori down stream
1	Temperature	^{0}C	28.2	28.3	28.3	28.4	28	28.2
2	pH	pH unit	7.69	7.68	7.61	7.7	7.69	7.64
3	Alkalinity	Mg/l	44	52	48	44	48	52
4	DO	Mg/l	6.8	6.7	6.9	6.8	7.6	7.5
5	COD	Mg/l	2.5	7.5	5	2.5	7.5	2.5
6	BOD	Mg/l	0.3	1.9	1.8	1.7	1.9	2.1
7	TDS	Mg/l	201	249	241	281	271	281
8	TH	Mg/l	96	116	112	108	112	120
9	Nitrate	Mg/l	0.18	0.3	0.24	0.16	0.18	0.34
10	Phosphate	Mg/l	ND	0.01	0.004	0.002	0.004	0.012
11	Chloride	Mg/l	19.4	24.5	19.4	24.5	24.5	29.5
12	Sulphate	Mg/l	12	16	14	14	13	14
13	T. coliform	MPN/10	1.8	84	63	50	63	94
14	F. coliform	MPN/10	<1.8	3.6	<1.8	<1.8	<1.8	3.6
15	total kjeldahl nitrogen	Mg/l	-	-	-	-	-	-

Results and Discussion

The seasonal variation in physico-chemical and bacteriological characteristics of river water from six sampling stations along the upper stretch of the Narmada River was evaluated during pre-monsoon (April–June 2025) and monsoon (July–September 2025) periods. The observed parameters revealed spatial and temporal variations influenced by hydrological processes and anthropogenic activities.

Temperature

Water temperature exhibited slight seasonal variation across all sampling stations, ranging from 27.8°C–28.2°C during April–June and 28.0°C–28.4°C during July–September. A marginal increase during the monsoon, particularly at Chandan Ghat, may be due to atmospheric conditions and surface runoff. The relatively stable temperature range indicates absence of thermal pollution and reflects natural climatic influence, providing favourable conditions for aquatic organisms. Variation in temperature is presented in Fig. 2.

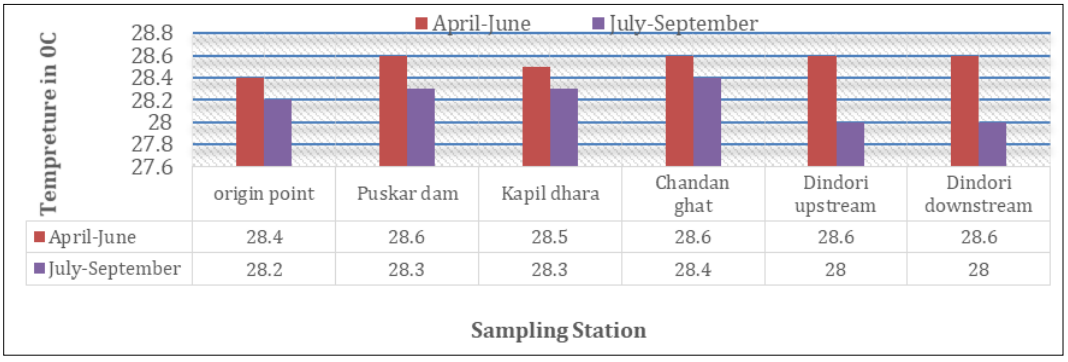


Fig 1

pH: pH values varied from 7.15–7.86 during the pre-monsoon and 7.61–7.70 in the monsoon season, indicating slightly alkaline conditions within BIS permissible limits (6.5–8.5). The alkalinity may result from carbonate and bicarbonate buffering in the river. Minimal seasonal fluctuation and a slight downstream increase reflect stable water quality. These conditions favour aquatic life and suggest absence of significant acidic or alkaline pollution (Fig. 2).

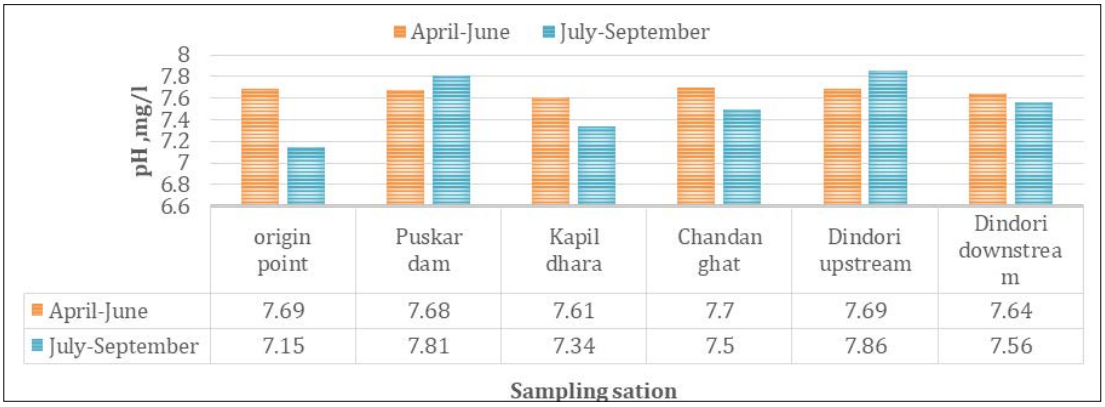


Fig 2

Total Alkalinity (TA): Total alkalinity ranged between 40–56 mg/L during April–June and 44–52 mg/L during July–September, indicating moderate buffering capacity and acceptable water quality. A gradual increase in alkalinity from upstream to downstream stations suggests mineral dissolution and possible anthropogenic influence. Slightly higher monsoon values may result from runoff carrying dissolved carbonates and bicarbonates. The variation in total alkalinity at different sampling locations is shown in Fig. 3.

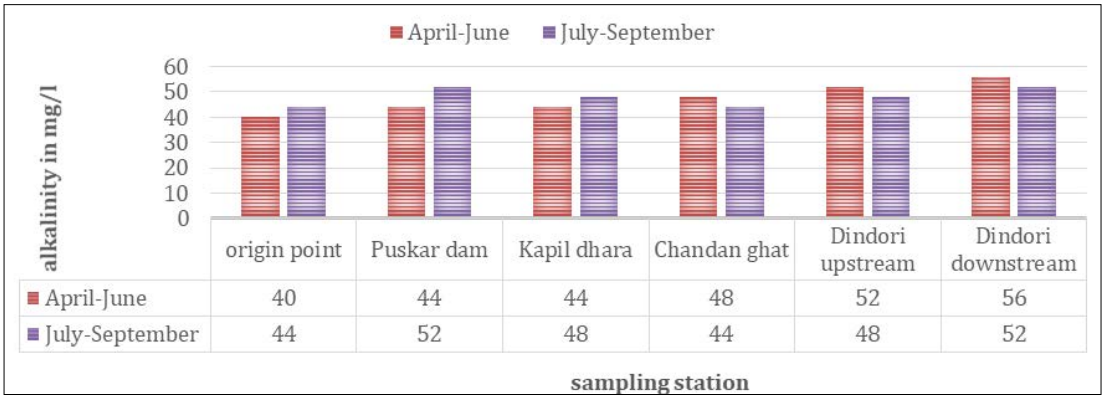


Fig 3

Dissolved Oxygen (DO): Dissolved oxygen (DO) levels ranged from 6.3–7.8 mg/L in the pre-monsoon and 6.7–7.6 mg/L during the monsoon, indicating well-oxygenated water. Higher DO at upstream stations reflects better aeration and lower organic load. A slight decline at certain sites during the monsoon may be due to increased organic matter and microbial activity. Overall, the values suggest healthy ecological conditions and minimal organic pollution (Fig. 4).

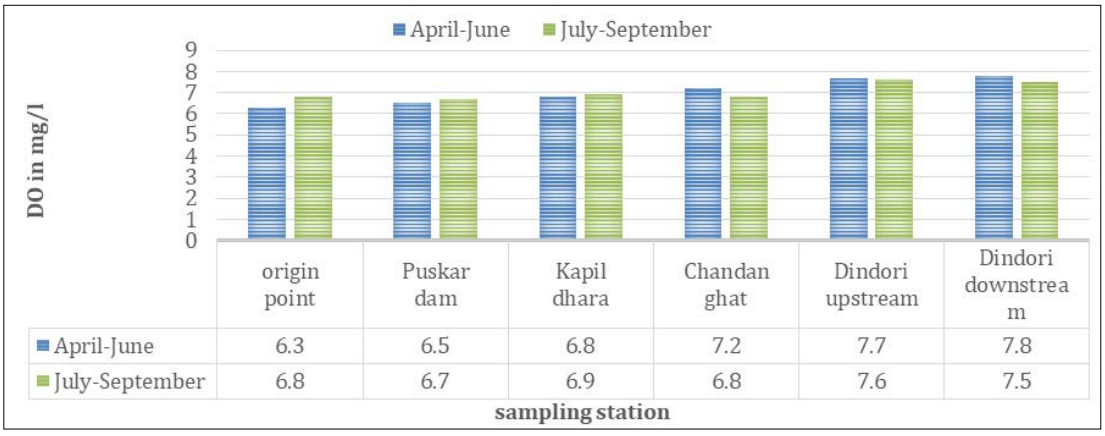


Fig 4

Chemical Oxygen Demand (COD): Chemical oxygen demand (COD) values ranged from 2.4–7.2 mg/L during April–June and 2.5–7.5 mg/L in July–September, indicating moderate organic pollution. Higher COD at Pushkar Dam and Dindori suggests localized contamination from domestic activities and surface runoff. Slightly elevated monsoon values may be due to increased organic load. However, overall levels remain within acceptable limits, reflecting moderate chemical pollution and manageable water quality conditions. Fig-5

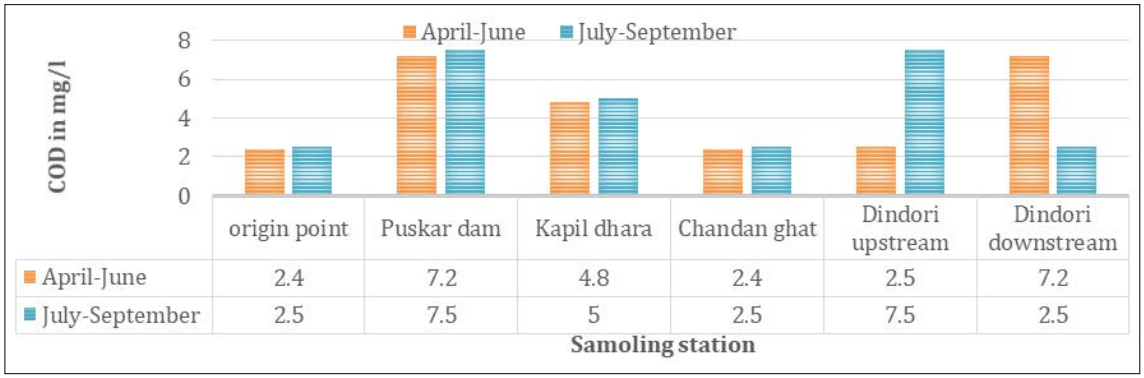


Fig 5

Biological oxygen Demand (BOD): Biochemical oxygen demand (BOD) values ranged from 0.2–1.9 mg/L during pre-monsoon and 0.3–2.1 mg/L in the monsoon season, indicating low to moderate organic pollution. Slightly higher monsoon values reflect enhanced microbial decomposition of organic matter carried by runoff. Lower BOD at upstream sites and gradual increase downstream suggest localized impacts. Overall, the low range indicates good self-purification capacity of the river, with moderate pollution observed at Dindori (Fig. 6).

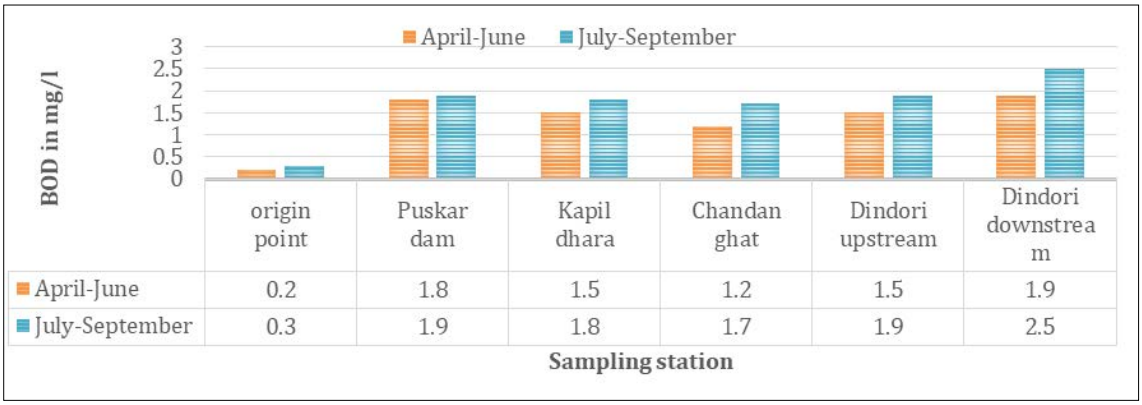


Fig 6

Total dissolved solids (TDS): Total dissolved solids (TDS) ranged from 168–228 mg/L in April–June and increased to 201–281 mg/L during July–September. The monsoon rise reflects soil erosion and runoff carrying dissolved minerals. Higher downstream values indicate mineral accumulation and anthropogenic inputs, though all values remained within permissible limits, indicating acceptable water quality. Fig.-7

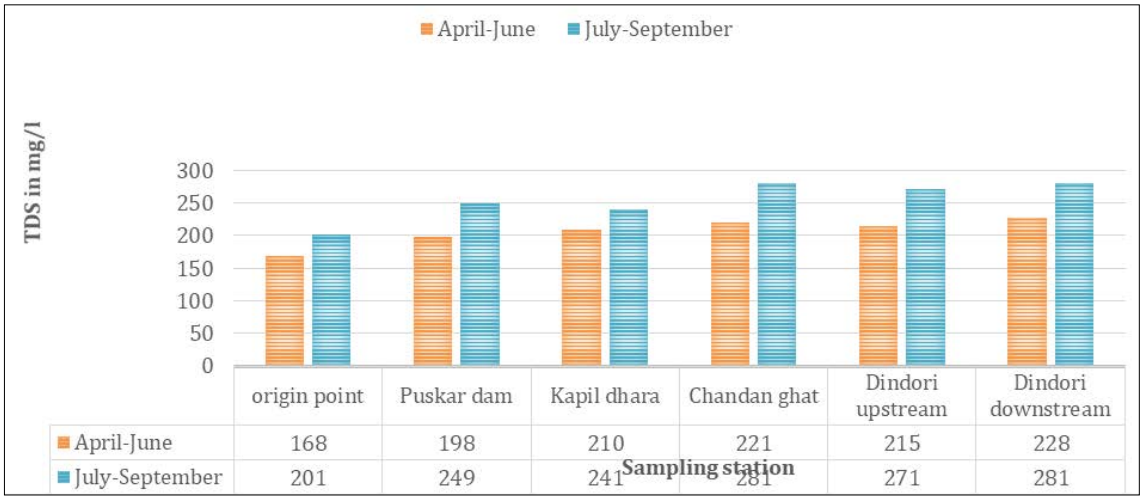


Fig 7

Total Hardness (TH): Total hardness ranged from 104–130 mg/L in the pre-monsoon and 96–120 mg/L during the monsoon, indicating moderately hard water. The values reflect the presence of calcium and magnesium salts mainly derived from geological formations. Slightly higher hardness at downstream stations suggests mineral accumulation and domestic inputs, while minimal seasonal variation indicates stable mineral composition of the river water.

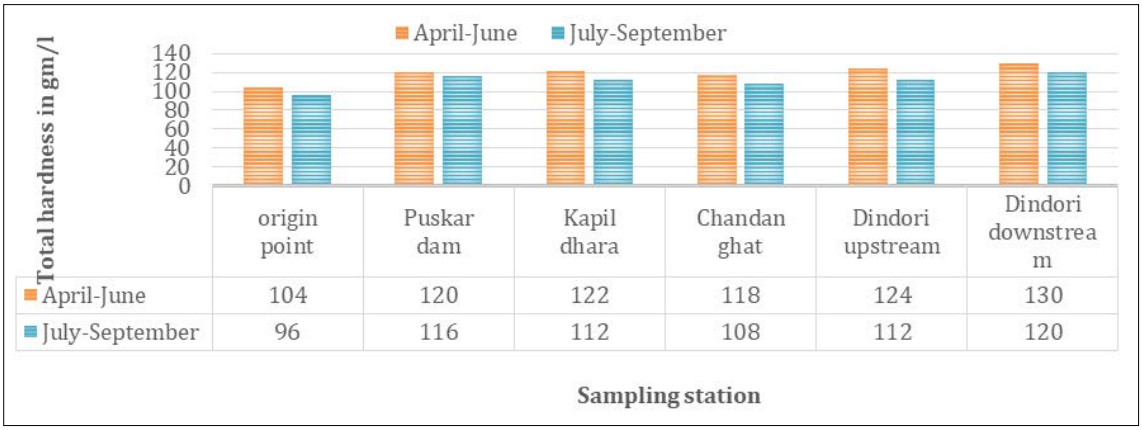


Fig 8

Nitrate: Nitrate concentration ranged from 0.16–0.20 mg/L during pre-monsoon and 0.16–0.34 mg/L in the monsoon season. Higher monsoon values indicate agricultural runoff, organic matter decomposition, and domestic discharge. Slightly elevated downstream levels were observed; however, all values remained within permissible limits, suggesting low risk of eutrophication**.**

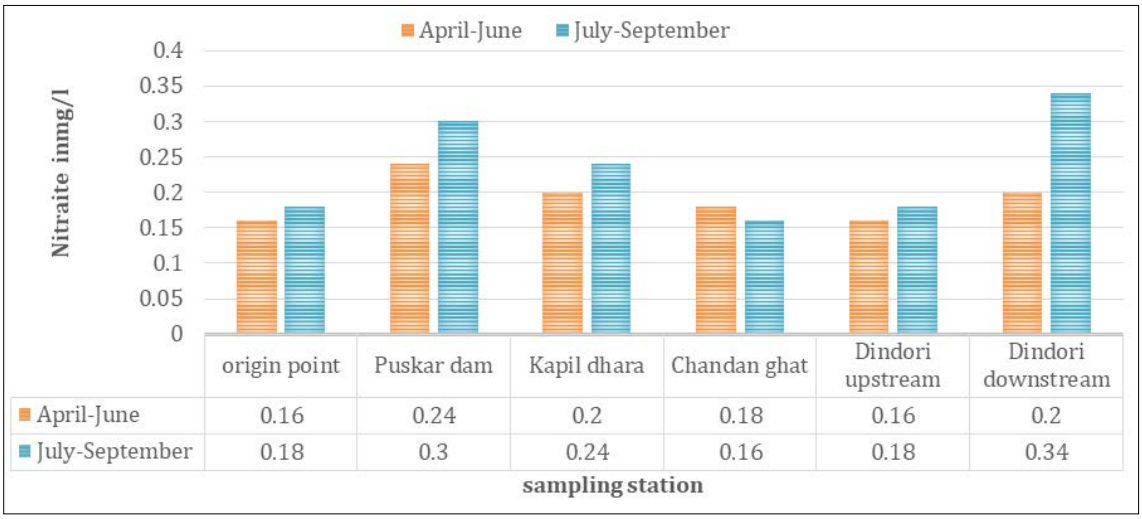


Fig 9

Phosphate (PO_4): Phosphate concentrations remained low (BDL–0.02 mg/L) across all sampling stations, indicating minimal nutrient enrichment. Slight downstream increases were observed, but values suggest absence of significant sewage input and low eutrophication risk.

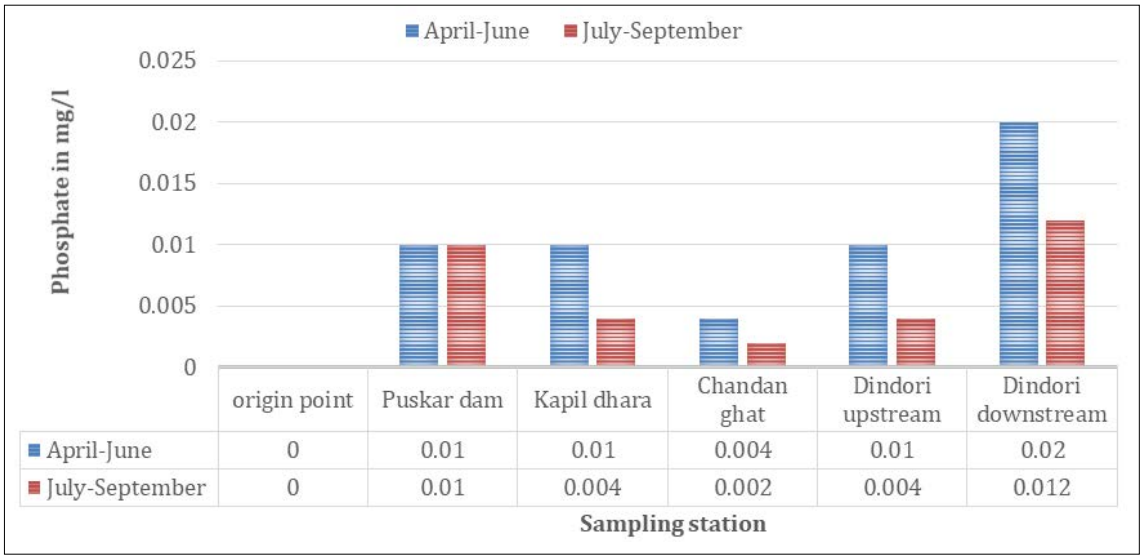


Fig 10

Chloride (Cl^-): Chloride concentrations ranged from 19.5–29.5 mg/L, while sulphate levels varied between 10–16 mg/L across seasons, indicating minimal sewage contamination and no major industrial discharge. Slightly higher chloride at Pushkar Dam and Dindori downstream suggests minor domestic influence; however, all values remained within safe permissible limits.

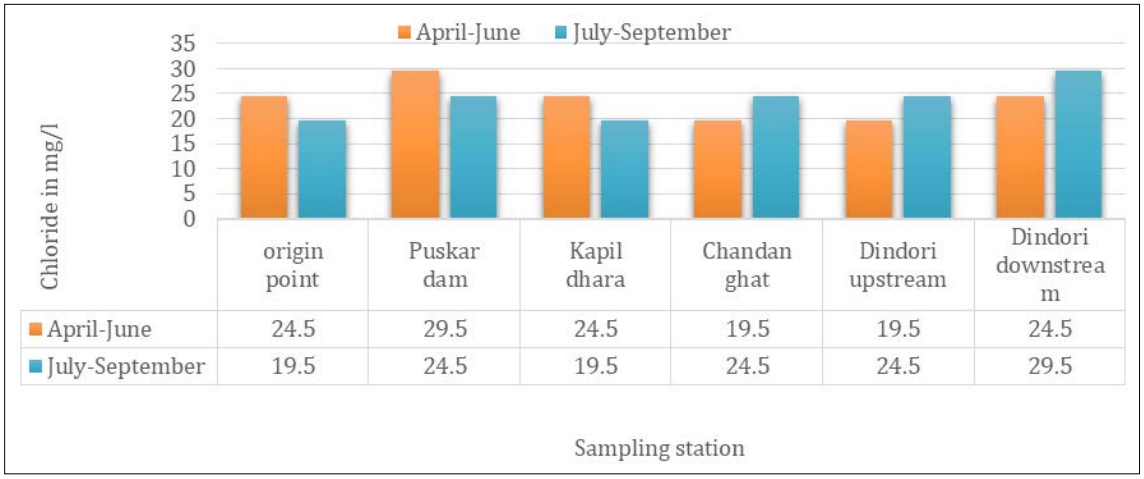


Fig 11

Sulphate: Sulphate concentrations remained low with minor seasonal variation. Slightly higher monsoon values may be due to mineral dissolution and surface runoff. The observed range indicates good water quality and absence of significant industrial contamination.

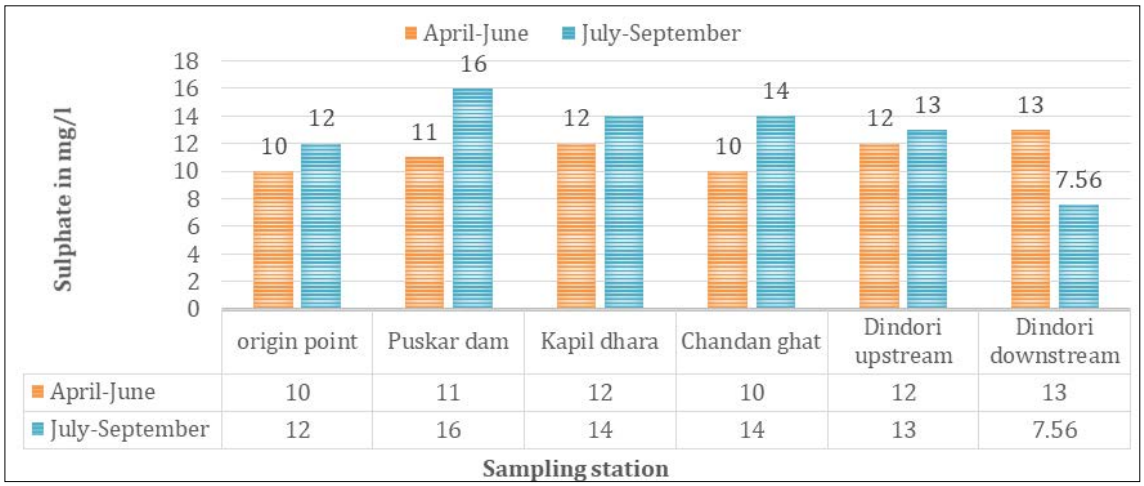
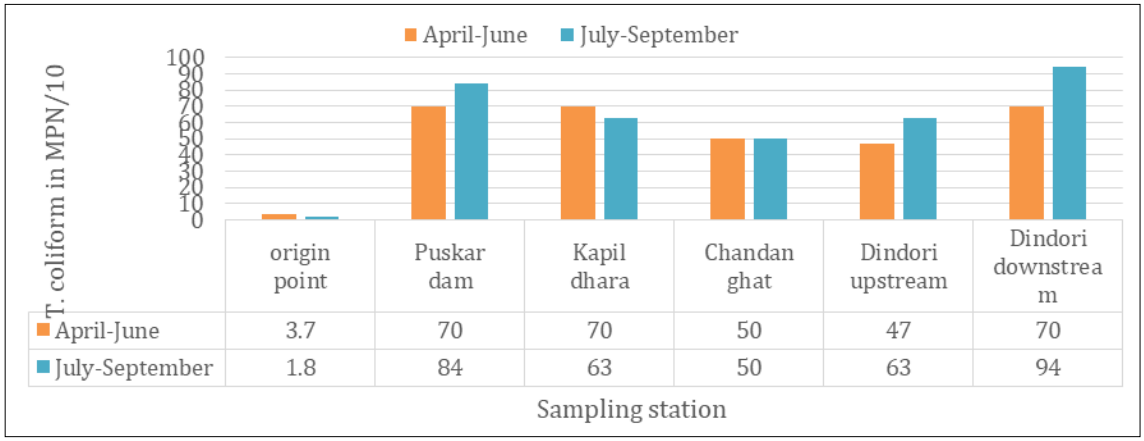


Fig 12

Bacteriological Characteristics: Total coliform counts increased at Pushkar Dam and downstream sites, especially during monsoon (up to 94 MPN/100 ml), indicating domestic waste and runoff contamination. Fecal coliform at selected locations suggests localized fecal pollution risk, while absence of Total Kjeldahl nitrogen indicates low organic nitrogen load in the river.



Seasonal and Spatial Variation: The study clearly demonstrates seasonal variation in water quality parameters. Monsoon season showed increased TDS, BOD, COD, nitrate, and coliform levels due to enhanced runoff and anthropogenic inputs. Downstream locations exhibited relatively higher pollution load compared to upstream sites, indicating the impact of human activities along the river stretch.

Overall Water Quality Assessment: Overall, the water quality of the Narmada River from origin to Dindori remained within permissible limits for most physico-chemical parameters. However, bacteriological contamination and slight increases in organic load at downstream locations indicate the need for continuous monitoring and effective pollution control strategies.

Conclusion

The present study provides a comprehensive evaluation of the physico-chemical and bacteriological characteristics of the upper stretch of the Narmada River from its origin to Dindori, Madhya Pradesh. The results revealed distinct spatial and seasonal variations in water quality parameters, largely influenced by natural hydrological processes, and localized anthropogenic activities. Most parameters, including pH, dissolved oxygen, alkalinity, total dissolved solids, hardness, nitrate, phosphate, chloride, and sulphate, remained within permissible limits, indicating generally good water quality and favourable conditions for aquatic life.

However, relatively higher values of BOD, COD, TDS, and microbial load at downstream locations, particularly during the monsoon season, reflect the impact of surface runoff, domestic discharge, and human activities along riverbanks. Although the river demonstrates strong self-purification capacity, the presence of coliform bacteria at certain sites highlights potential public health risks and emphasizes the necessity of adequate water treatment before consumption.

The study confirms that the river presently supports aquatic biodiversity, irrigation, and domestic uses; however, increasing anthropogenic pressure may threaten its long-term ecological sustainability. Therefore, sustainable river management requires continuous monitoring, strict regulation of domestic and agricultural discharge, effective wastewater treatment, protection of riparian vegetation, community awareness, and enforcement of environmental regulations to preserve river health and ensure sustainable freshwater utilization.

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