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Environmental Assessment of Narmada River Water Quality at Pilgrim Sites: Seasonal Variations and Pollution Impact

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ABSTRACT

The Narmada River is one of India's most sacred and ecologically significant rivers, providing water for domestic use, agriculture, fisheries, and religious activities. In recent decades, increasing urbanization, agricultural runoff, untreated sewage discharge, and large-scale pilgrimage activities have adversely affected its water quality. The present study evaluates the seasonal variation in physicochemical parameters and overall water quality of the Narmada River at selected pilgrimage sites between Hoshangabad (Narmadapuram) and Omkareshwar, Madhya Pradesh. Water samples were collected during summer, monsoon, and winter seasons and analyzed for pH, dissolved oxygen (DO), total dissolved solids (TDS), chemical oxygen demand (COD), hardness, chloride, and electrical conductivity using standard methods. A Water Quality Index (WQI) was computed to assess the suitability of water for human use.

The results reveal significant spatial and seasonal variations in water quality. Sites such as Bandrabhan, Kharra Ghat, Kheda Ghat, and Abhay Ghat exhibited good water quality, whereas Sethani Ghat and Narmada Ghat showed poor water quality due to high organic pollution and anthropogenic pressure. Elevated COD, turbidity, and hardness values were observed particularly during the monsoon season. The study highlights the environmental and public health implications of deteriorating river water quality at pilgrimage centers and emphasizes the urgent need for improved wastewater treatment, effective solid waste management, and sustainable river management strategies.

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KEYWORDS: *Narmada River, Water Quality Index, Physico-chemical parameters, Pilgrimage sites, Seasonal variation, Surface water pollution.*

1. INTRODUCTION

Rivers are vital freshwater resources that sustain ecological balance, economic development, and human civilization. In India, rivers also possess immense religious and cultural importance, serving as centers for pilgrimage and spiritual practices [1]. The Narmada River, the largest west-flowing river of India, originates from the Amarkantak Plateau in Madhya Pradesh and flows approximately 1,312 km before draining into the Arabian Sea. It is revered as one of the seven sacred rivers of Hinduism and supports millions of people along its course [2].

Despite its significance, the Narmada River has been subjected to increasing anthropogenic stress due to urbanization, industrial growth, agricultural intensification, and mass religious activities [3]. Pilgrimage centers such as Hoshangabad and Omkareshwar experience heavy human influx throughout the year, leading to the discharge of untreated sewage, solid waste, ritual offerings, and idol immersion materials into the river [4 – 5]. These activities alter the physicochemical characteristics of river water and degrade its ecological health.

Water quality assessment is an essential tool for understanding pollution levels, identifying contamination sources, and ensuring sustainable water management [6]. Among various assessment techniques, the Water Quality Index (WQI) is widely used to integrate multiple water quality parameters into a single numerical value that represents the overall quality of water [7 – 8]. The present study aims to assess the water quality of the Narmada River between Hoshangabad and Omkareshwar using physicochemical analysis and WQI, with special emphasis on the impact of pilgrimage-related activities [9 – 10].

2. Study Area

The study area covers a stretch of the Narmada River between Hoshangabad (Narmadapuram) and Omkareshwar in Madhya Pradesh, India. This region is characterized by intense religious, domestic, and agricultural activities.

Hoshangabad is a major riverside town known for Sethani Ghat, where large numbers of devotees gather for ritual bathing, especially during religious festivals. The town receives significant domestic sewage discharge, which directly enters the river.

Omkareshwar is one of the twelve Jyotirlingas of Lord Shiva and is situated on Mandhata Island at the confluence of the Narmada and Kaveri rivers. The town attracts thousands of pilgrims daily, resulting in substantial anthropogenic pressure on river water quality.

The region experiences a subtropical climate with hot summers, a monsoon season characterized by heavy rainfall, and mild winters. Seasonal variations strongly influence river flow, dilution capacity, and pollutant concentration.

3. Materials and Methods

3.1. Sampling Strategy

Water samples were collected from selected ghats along the Narmada River between Hoshangabad and Omkareshwar. Sampling was conducted during three distinct seasons—summer, monsoon, and winter—to capture seasonal variability. The grab sampling method was adopted, and samples were collected in clean polyethylene bottles.

3.2. Physico-Chemical Analysis

Collected samples were analyzed for pH, dissolved oxygen (DO), total dissolved solids (TDS), electrical conductivity, total hardness, chloride, and chemical oxygen demand (COD). All analyses were performed following standard methods recommended by APHA, WHO, and BIS. Proper quality control and calibration procedures were maintained throughout the analysis.

3.3. Water Quality Index (WQI) Calculation

The overall water quality of the Narmada River was assessed using the Weighted Arithmetic Water Quality Index (WQI) method, which integrates multiple physicochemical and biological parameters into a single numerical value representing the status of water quality. This method is widely used in river water quality studies due to its simplicity, reliability, and suitability for comparing spatial and seasonal variations.

Selection of Parameters

In the present study, the WQI was computed using the following parameters: temperature, turbidity, pH, electrical conductivity, total dissolved solids (TDS), total hardness, chloride, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total coliform. These parameters were selected based on their significance in determining drinking and surface water quality and their relevance to river pollution assessment.

Assignment of Standard and Ideal Values

For each water quality parameter, a standard permissible value (Si) was adopted from Bureau of Indian Standards (BIS 10500:2012) and World Health Organization (WHO) guidelines. The ideal value (Vi) represents the concentration of the parameter in pure water. For most parameters, the ideal value was considered as zero, except for pH and dissolved oxygen. The ideal value for pH was taken as 7.0, representing neutrality, while for dissolved oxygen it was considered as 14.6 mg/L, corresponding to saturation at standard conditions.

Calculation of Unit Weight (Wi)

The unit weight (Wi) for each parameter was calculated using the inverse of the respective standard value, ensuring that parameters with lower permissible limits exert a greater influence on the overall index. The unit weight was computed as:

$$W_i - \frac{k}{S_i}$$

where

W_i= unit weight of the ith parameter

S_i= standard permissible value of the ith parameter

k= proportionality constant

The constant $k$was determined such that the sum of all unit weights equals unity:

$$\sum W_i = 1$$

Calculation of Quality Rating (Qi)

The quality rating scale (Qi) represents the relative deviation of observed values from their respective standards. Since different parameters influence water quality in different ways, the calculation of Qi was adapted according to the nature of each parameter:

- For parameters where higher concentrations indicate deterioration of water quality (such as turbidity, TDS, total hardness, chloride, BOD, COD, and total coliform), Qi was calculated as:

$$Q_i = \frac{V_i}{S_i} \times 100$$

- For pH, where deviation from neutrality affects water quality, Qi was calculated as:

$$Q_{pH} = \frac{|V_i - 7|}{|S_i - 7|} \times 100$$

- For dissolved oxygen (DO), which improves water quality with increasing concentration, Qi was calculated using an inverse relationship:

$$Q_{DO} - \frac{S_i - V_i}{S_i - V_{ideal}} \times 100$$

where
V_i= observed value of the parameter
V_{ideal}= ideal value of the parameter

Computation of Water Quality Index
The overall Water Quality Index was calculated by aggregating the weighted quality ratings of all parameters using the following expression:

$$\text{WQI} = \frac{\sum(W_i \times Q_i)}{\sum W_i}$$

Since the unit weights were normalized, the denominator $\sum W_i$ equals unity, simplifying the computation.

Classification of Water Quality
The computed WQI values were classified into different water quality categories to facilitate interpretation:

WQI Range	Water Quality Class
0–50	Excellent
51–100	Good
101–200	Poor
201–300	Very Poor
>300	Unsuitable for use

4. Results and Discussion
The physicochemical analysis revealed notable spatial and seasonal variations in water quality across the study area. pH values at most sampling sites remained within permissible limits, indicating slightly alkaline conditions. Dissolved oxygen levels were relatively high at less disturbed sites such as Bandrabhan and Kharra Ghat but showed a decline at Sethani Ghat and Narmada Ghat due to increased organic pollution.

TDS, electrical conductivity, and hardness values were elevated at sites influenced by urban discharge and pilgrimage activities, reflecting the contribution of domestic sewage and surface runoff. COD values exceeded permissible limits at Sethani Ghat and Narmada Ghat, indicating high organic load and reduced self-purification capacity of the river. Turbidity and COD values were particularly high during the monsoon season due to increased runoff and waste inflow.

The computed WQI values categorized Bandrabhan, Kharra Ghat, Kheda Ghat, and Abhay Ghat as having good water quality, while Sethani Ghat and Narmada Ghat were classified under poor water quality. These findings highlight the significant impact of anthropogenic activities on river water quality at pilgrimage centers.

Table 4.1: Monthly variation of Water Quality Index (WQI) values at selected monitoring stations of the Narmada River

Month	Bandar Bhan Ghat	Sethani Ghat	Kharra Ghat	Kheda Ghat	Narmada Ghat	Abhay Ghat
July	143.880	168.045	152.671	154.979	193.631	159.144
Aug	159.784	192.004	167.294	165.709	215.898	167.787
Nov	42.344	67.172	46.098	42.518	71.805	45.934
Dec	39.281	61.744	46.709	45.227	70.111	48.687
April	52.128	64.109	57.305	43.324	70.456	52.547
May	62.823	66.187	61.671	52.941	72.335	58.693
Average WQI	**83.373**	**103.210**	**88.624**	**84.116**	**115.705**	**88.799**

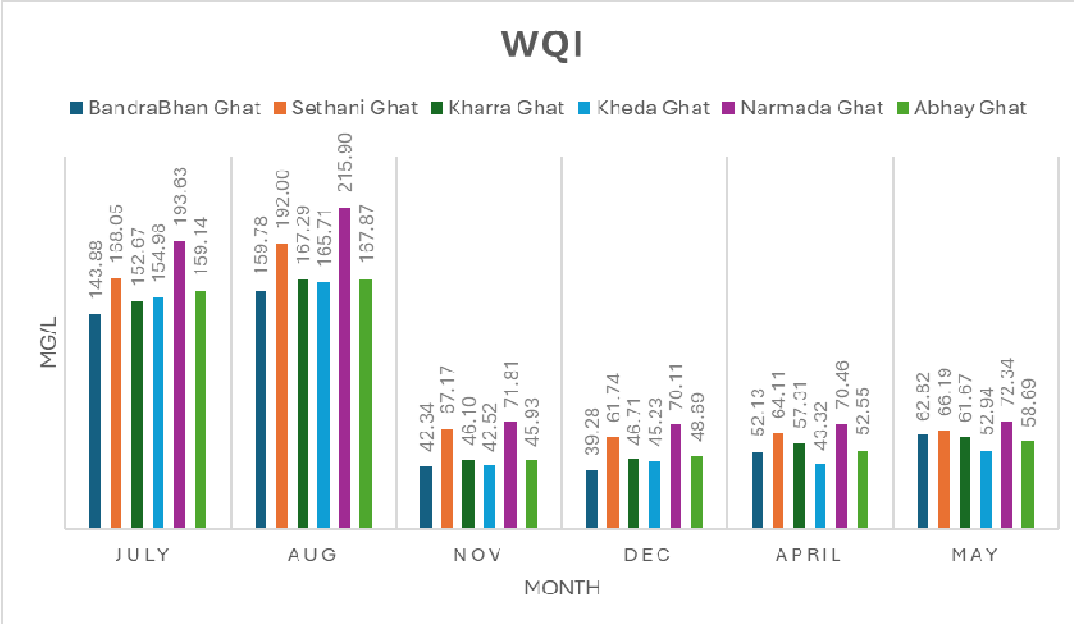

Figure 4.1: Monthly variation of Water Quality Index (WQI) at selected ghats of the Narmada River between Hoshangabad and Omkareshwar

Table 4.2: Average Water Quality Index (WQI) and corresponding water quality classification at different ghats of the Narmada River

STATIONS	AVERAGE WQI	Water quality status
BANDARBHAN	83.37	good water quality
SETHANI GHAT	103.21	poor water quality
KHARRAGHAT	88.62	good water quality
KHEDA	84.11	good water quality
NARMADA GHAT	115.70	poor water quality
ABHAY GHAT	88.79	good water quality

Among the selected monitoring stations, Sethani Ghat and Narmada Ghat exhibited comparatively higher average WQI values, categorizing them under the *poor* water quality class. This deterioration in water quality can be attributed to intense pilgrimage activities, mass bathing, direct disposal of religious offerings, and continuous urban wastewater inflow. In contrast, Bandra Bhan Ghat, Kharra Ghat, Kheda Ghat, and Abhay Ghat showed comparatively lower WQI values, falling under the *good* water quality category, indicating relatively lesser anthropogenic stress and better self-purification capacity of the river at these locations.

Seasonal analysis revealed a distinct trend, with higher WQI values during the monsoon months (July–August), reflecting deteriorated water quality due to increased runoff carrying suspended solids, nutrients, and microbial contaminants into the river. Conversely, improved water quality during the winter months (November–December) was observed, which may be attributed to reduced runoff, settling of suspended particles, and enhanced dilution effects. During the summer season, moderate degradation in water quality was noted, possibly due to reduced river flow, higher temperatures, and increased concentration of pollutants.

Overall, the findings indicate that urbanization and human activities play a significant role in influencing the water quality of the Narmada River in the Hoshangabad–Omkareshwar region. While certain ghats maintain acceptable water quality levels, others are experiencing noticeable degradation, emphasizing the need for improved sewage management, regulation of anthropogenic activities at pilgrimage sites, and continuous monitoring to protect the ecological and public health integrity of the river.

5. Environmental and Public Health Implications

Deterioration of water quality at major pilgrimage sites poses serious environmental and public health risks. Poor water quality threatens aquatic biodiversity and disrupts ecological balance. The use of contaminated river water for bathing, religious rituals, irrigation, and domestic purposes increases the risk of waterborne diseases among pilgrims and local communities. Long-term exposure to polluted water may also affect agriculture, fisheries, and local livelihoods.

6. Conclusions

The Narmada river is also called "Rewa" meaning "leaping one" it is a holy river often considered purer than the Ganges with a sacred circumambulation (Narmada Parikrama) perform by the devotees. It flows through central India shaping landscapes and spiritual journeys notably at Hoshangabad known for its broad banks and at Omkareshwar a sacred island where the river splits to form a holy land adorned with temples and waterfalls making siginificants spiritual sites along its ancient life giving course from Amarkantak.

The literature riview on the water assessment of the Narmada river in Hoshangabad and Omkareshwer highlighted significant pollution from agricultural run off, domestic sewage and industrial effluents impacting on parameters like BOD, COD.

The present study was undertaken to assess the water quality status of the Narmada River at selected ghats in the Hoshangabad–Omkareshwar region using physicochemical, biological, and Water Quality Index (WQI) analysis. The results clearly indicate that the river water quality exhibits significant spatial and seasonal variability, primarily influenced by anthropogenic activities, hydrological conditions, and land-use practices along the riverbanks.

Analysis of individual physicochemical parameters revealed elevated levels of chemical oxygen demand (COD) at Sethani Ghat (30.2 mg/L) and Narmada Ghat (31.7 mg/L), indicating a higher organic pollution load at these locations. Increased values of turbidity, biochemical oxygen demand (BOD), COD, and total coliform were observed at certain sites, particularly during the monsoon season, reflecting the impact of surface runoff, urban wastewater discharge, and increased human activities. Correspondingly, reduced dissolved oxygen levels were recorded at these sites, signifying enhanced biological activity and pollution stress.

The pH values at Bandrabhan Ghat and Kheda Ghat were found to be within permissible limits as prescribed by BIS and WHO standards, indicating relatively stable acid–base conditions at these locations. Turbidity levels exceeded acceptable limits during the monsoon season at all sampling sites, resulting in increased suspended matter and reduced water clarity. The water sample from Narmada Ghat exhibited a total hardness value of 157 mg/L, classifying it as very hard water, which may lead to adverse health effects such as hair fall, skin pigmentation, and gastrointestinal issues upon prolonged consumption.

Seasonal analysis revealed deterioration in water quality during the monsoon months due to contaminant inflow from catchment runoff, while improved conditions were observed during the winter season. Moderate degradation during summer was attributed to reduced river flow and increased concentration of pollutants.

The Water Quality Index provided an integrated assessment of overall water quality. The average WQI values for Bandrabhan Ghat, Kheda Ghat, Kharra Ghat and Abhay Ghat ranged from 83.37 to 88.79 categorizing the water as good and safe for drinking purposes. In contrast, Sethani Ghat and Narmada Ghat were classified under the poor water quality category, indicating that the water at these locations is unsuitable for direct consumption without treatment. Higher pollution stress at these sites is associated with intense pilgrimage activities, urban wastewater discharge, and increased anthropogenic pressure.

Overall, the study demonstrates that the water quality of the Narmada River at Hoshangabad is comparatively better than that reported for Omkareshwar. However, the increasing impact of urbanization and human activities poses a significant threat to river health. The findings emphasize the urgent need for effective water quality management strategies, regular monitoring, and pollution control measures to preserve the ecological integrity and potable water potential of this vital river system.

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