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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, one of India's most significant water bodies, plays a crucial role in the socio-cultural, economic, and environmental framework of the region. However, increasing anthropogenic activities, including religious practices, urbanization, and industrial discharge, have significantly impacted its water quality. This study provides an environmental assessment of Narmada River water at key pilgrim sites between Hoshangabad and Omkareshwar, analyzing seasonal variations in physico-chemical parameters such as pH, dissolved oxygen (DO), total dissolved solids (TDS), chemical oxygen demand (COD), chloride, hardness, and electrical conductivity. The results indicate that water quality varies across locations and seasons, with Bandrabhan (Site 1) showing the best water quality, adhering to BIS and WHO standards, while sites like Sethanighat and Narmada Ghat exhibit high pollution levels due to untreated sewage and urban runoff. The Water Quality Index (WQI) analysis categorizes Bandrabhan, Kharraghat, and Kheda as having "good water quality," whereas Sethanighat, Abhay Ghat, and Narmada River are classified under "poor water quality."

Keywords: Narmada River, Water Quality Assessment, Physico-Chemical Parameters, Water Pollution, Pilgrim Sites, Seasonal Variation, Water Quality Index (WQI), Environmental Impact, Wastewater Management, Surface Water Contamination, Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS).

I. INTRODUCTION

Rivers are vital natural resources that support biodiversity, agriculture, drinking water supply, and socio-economic activities. However, rapid urbanization, industrialization, and increasing anthropogenic activities have led to significant degradation of river water quality. Among India's major rivers, the Narmada River holds immense ecological, economic, and cultural importance, serving as a primary water source for millions of people. It is also a sacred river, attracting thousands of pilgrims who engage in religious rituals along its banks. However, pollution from domestic sewage, religious offerings, and agricultural runoff poses a serious threat to its water quality.

This study aims to assess the environmental health of the Narmada River at key pilgrim sites between Hoshangabad and Omkareshwar by analyzing seasonal variations in physico-chemical parameters. Parameters such as pH, dissolved oxygen (DO), total dissolved solids (TDS), chemical oxygen demand (COD), chloride, hardness, and electrical conductivity are evaluated to determine the extent of pollution and its impact on water quality.

The primary objectives of this study are to analyze seasonal fluctuations in key water quality parameters across different sites,to evaluate the Water Quality Index (WQI) and compare it with BIS and WHO standards. Also,

1. To identify the major sources of pollution affecting the river at these locations.
2. To assess the environmental and social implications of water pollution.
3. To provide policy recommendations for sustainable water resource management and pollution control.

The findings of this study will contribute to a better understanding of the impact of human activities on river ecosystems and help in formulating strategies for conservation and sustainable management of the Narmada River. By implementing appropriate pollution control measures, it is possible to preserve the river's ecological integrity and ensure its continued use for religious, domestic, and agricultural purposes.

II. LITERATURE REVIEW

Gupta et al. (2024) conducted a detailed analysis of heavy metal concentrations in the upper stretches of the Narmada River, focusing on the pre-monsoon and post-monsoon seasons. The study highlighted the presence of heavy metals such as Aluminum (Al), Iron (Fe), Zinc (Zn), and others in the river water, with the concentrations varying between the seasons. The pollution indices, namely the Heavy Metal Evaluation Index (HEI) and the Heavy Metal Pollution Index (HPI), categorized the water as medium to heavily polluted. These findings indicate a significant threat to human health and emphasize the need for stringent monitoring and remediation efforts at these pilgrim sites.

Jain et al. (2024) focused on the physicochemical and microbial parameters of the Narmada River at Riddhnath Ghat in the Harda District. The study revealed high levels of microbial pollution, particularly the presence of coliform bacteria, salmonellae, and vibrio, which pose severe health risks to pilgrims. The research also noted

that the major sources of pollution were polythene, coconut offerings, and other types of waste discarded into the river. The study underscores the urgent need for better waste management practices to mitigate the health hazards associated with waterborne diseases such as cholera and dysentery.

Bilimoria et al. (2024) explored the cultural and historical significance of water in the Indic world, with a particular focus on the Narmada River. The study provided insights into the sacred and profane roles of water in religious and secular ceremonies from Vedic times to the present day. The research underscored the deep connection between the river and the cultural practices of the local communities, highlighting the importance of maintaining the ecological health of the Narmada to preserve its cultural heritage.

Rathore et al. (2023) examined the impact of religious activities, particularly mass bathing during events like Amavasya and solar eclipses, on the water quality of the Narmada River. The study found significant increases in Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), Total Dissolved Solids (TDS), and other physicochemical parameters post these events. The research emphasized that such activities contribute to the deterioration of water quality, necessitating the implementation of measures to control pollution during religious gatherings.

Kochara et al. (2023) highlighted the ecological importance of aquatic insects in the Narmada River, identifying various species across different microhabitats. The study demonstrated that the river's physicochemical parameters were within WHO limits, suggesting a relatively healthy aquatic ecosystem. However, the research also pointed out the seasonal variations in water quality, with higher pollution levels recorded during the monsoon months.

Kumar et al. (2023) discussed the socio-political challenges of water flow regulation in the Narmada River basin, particularly in Omkareshwar. The study explored the community's struggles with erratic water flows due to large-scale regulatory practices and called for a repoliticization of water management to better address local needs. This perspective adds a critical dimension to the environmental assessment, emphasizing the need for inclusive and participatory approaches to river management.

III. METHODOLOGY

3.1 Sampling Strategy:

Water samples are collected bimonthly from multiple monitoring sites between Hoshangabad and Omkareshwar. Seasonal samples (summer, winter, rainy) were collected to capture seasonal variability in the water quality. Water of the river Narmada collected from 06 sampling stations, 3 from hoshangabad and other 3 from omkareshwar.

3.2 Methods

The methods given in APHA (1998) were followed.

3.2.1 Lab and sampling procedure

In order to maintain uniformity, water samples from the 6 stations along the course of river Narmada were collected at a time on a single suitable day for the given season. The same was repeated for all seasons during the study period. It was planned in such a way that the 6 samples for the given season were collected on the same day at the time in the morning between 10.00 am to 11.00 am. Two polythene containers (One litre bottle for physico-chemical parameters and 100 ml bottle for concentration of metallic elements) were rinsed with the river water thrice and collected the subsurface water and then capped them tightly while the bottles were in submerged condition at the sampling stations. The samples were taken to the labs for physico-chemical analysis; all were given same procedure and done on the same day, except BOD. BOD was measured after five days incubation process. 1ml of Conc. Nitric acid was added to the second sampled container for storage purpose, packed properly and transported for the heavy metal analysis.

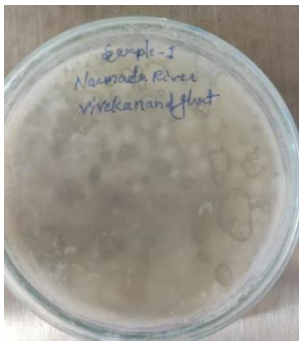

Fig 1 Sample 1 Sethani ghat

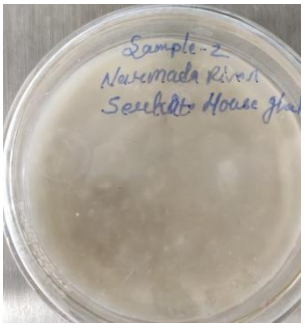

Fig 2 Sample 2 Kharra ghat

Fig 3 Water sample in incubator

Fig 4 Titrate water with sodium thio sulphate

Fig 5 Titration

Fig 6 COD Apparatus

IV. RESULT

The present study was intended to analyse various water parameters through the course of river Narmada in different sites at Narmada puram and omkareshwar.

To find out the seasonality for this trend during a total course of river, Six sampling stations covering all kinds of human activities were identified and studied for a period of one year July2023-May 2024

The first three sampling station-Bandarbhan, sethani ghat and kharra ghat is located at Narmadapuram, and the other three kheda, abhay ghat and narmadaghat in omkareshwar.

Properties such as Appearance, Temperature, Turbidity, Colour, Total Hardness, Ph, Conductivity, TDS, Chloride, DO, BOD, COD, T.coliform are determined at each station.

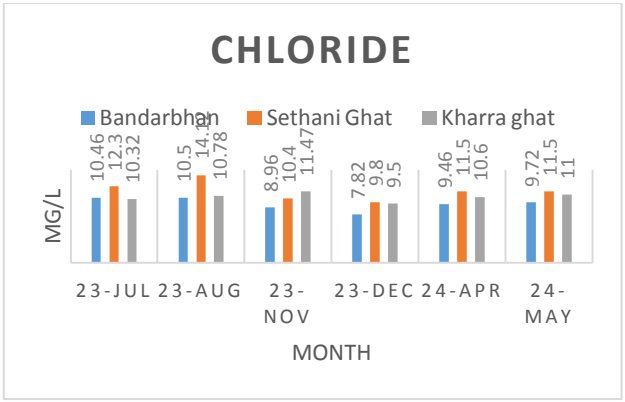

Fig 7 Chloride content in water in each station in Narmadapuram

Highest value of Chloride 14.12 mg/l has been observed at Sethanighat (site 2) in the month of August 2023 and the lowest value of Chloride 7.82 mg/l is recorded at Bandrabhan (site 1) in the month of December 2023.

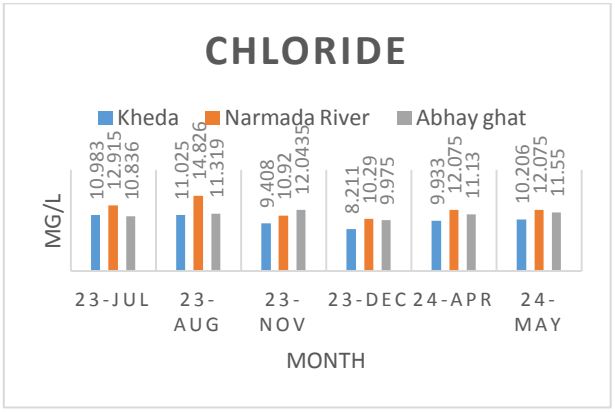

Fig 8 Chloride content in water in each station in Omkareshwar

Highest value of Chloride 14.8 mg/l has been observed at Narmada Ghat (site 2) in the month of August 2023 and the lowest value of Chloride 8.2 mg /l is recorded at Kheda (site 1) in the month of December 2023.

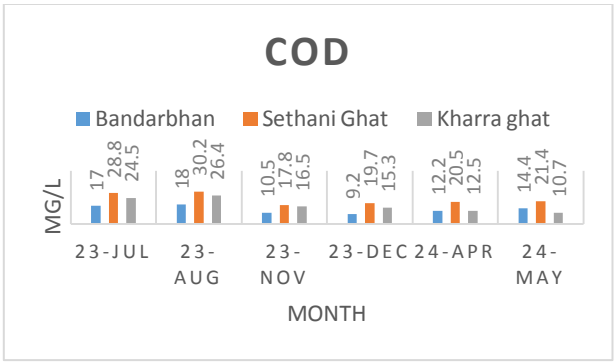

Fig 9 COD of water in each station in Narmadapuram

Lowest value of COD 9.2 mg/l has been observed at Bandrabhan (site 1) in the month of December 2023 and highest COD 30.2 mg/l value is recorded at Sethanighat (site 2) in the month of August 2023.

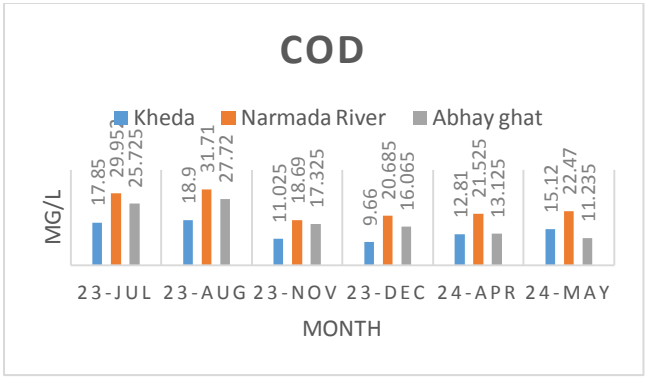

Fig 10 COD of water in each station in Omkareshwar

Lowest value of COD 9.7 mg/l has been observed at Kheda(site 1) in the month of December 2023 and highest COD 31.7 mg/l value is recorded at Narmada Ghat (site 2) in the month of August 2023.

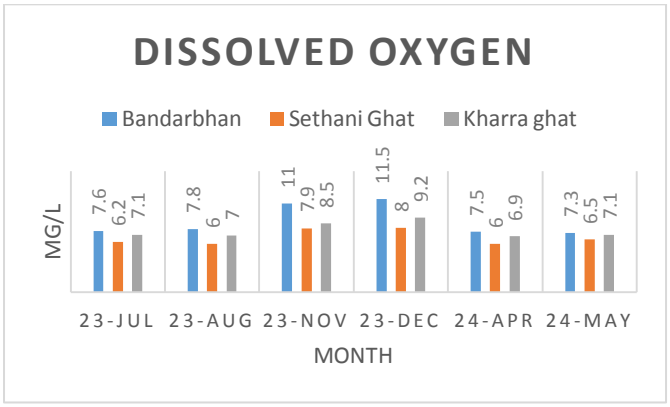

Fig 11 DO of water in each station in Narmadapuram

Highest value of DO (disolved oxygen) 11.5 mg/l has been observed at Bandrabhan (site 1) in the month of December 2023 and the lowest value of DO 6.0 is recorded at Sethanighat in the month of August 2023 and April 2024,

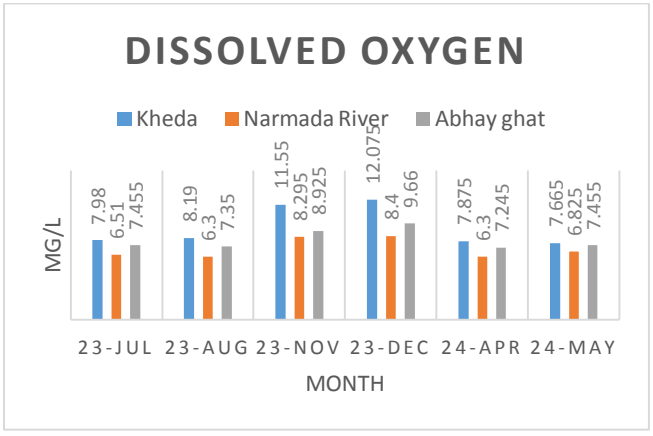

Fig 12 DO of water in each station in Omkareshwar

Highest value of DO (disolved oxygen) 12.1 mg/l has been observed at Kheda(site 1) in the month of December 2023 and the lowest value of DO 6.3 mg/l is recorded at Narmada Ghat in the month of August 2023 and April 2024,

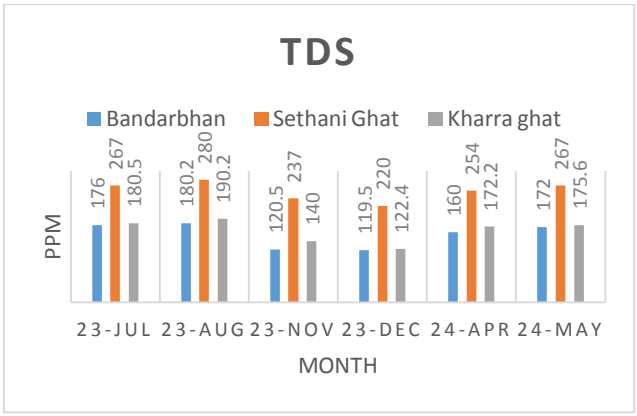

Fig 13 TDS of water in each station in Narmadapuram

Lowest value of TDS 119.5 ppm is recorded at Bandrabhan (site:1) in the month of December 2023 and the highest value of TDS 280 ppm has been observed at Sethanighat in the month of August 2023.

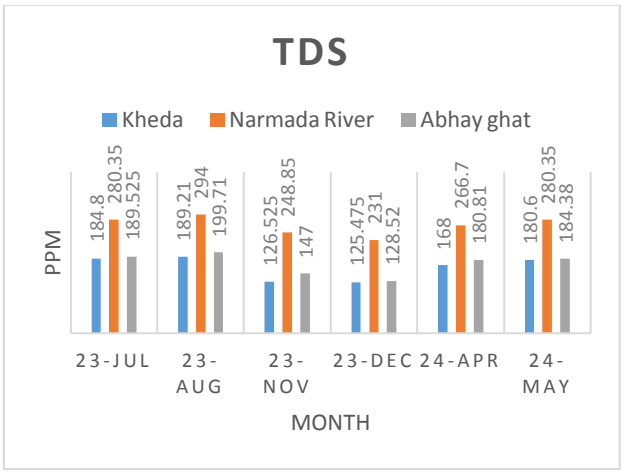

Fig 14 TDS of water in each station in Omkareshwar

Lowest value of TDS 125 ppm is recorded at Kheda(site:1) in the month of December 2023 and the highest value of TDS 294 ppm has been observed at Narmada Ghat in the month of August 2023.

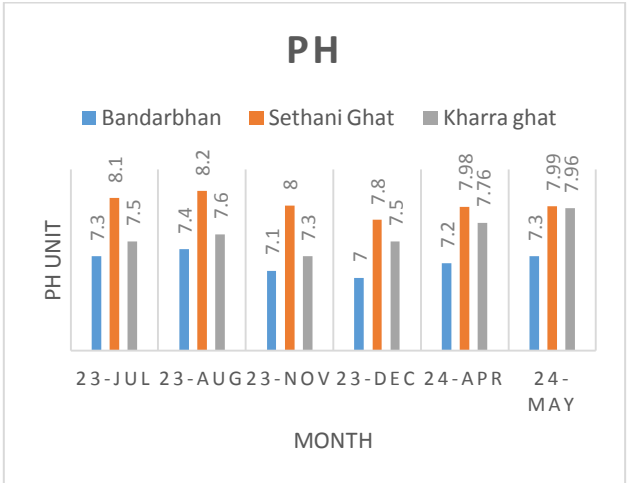

Fig 15 PH of water in each station in Narmadapuram

Lowest value of PH 7 is recorded at Bandrabhan (site:1) in the month of December 2023 and the highest value of PH 8.2 ppm has been observed at Sethanighat in the month of August 2023.

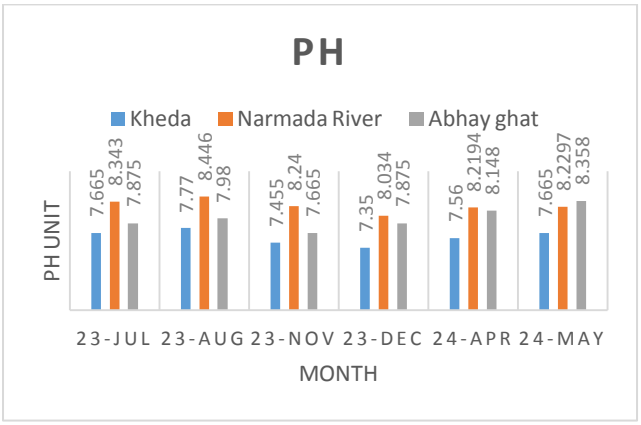

Fig 16 PH of water in each station in Omkareshwar

Lowest value of PH 7.4 is recorded at Kheda(site:1) in the month of December 2023 and the highest value of PH 8.4 has been observed at Narmada Ghat in the month of August 2023.

Lowest value of Conductivity 121.5 mmhos/cm is recorded at Bandrabhan (site:1) in the month of December 2023 and the highest value of Conductivity 287.3 mmhos/cm has been observed at Sethanighat in the month of August 2023.

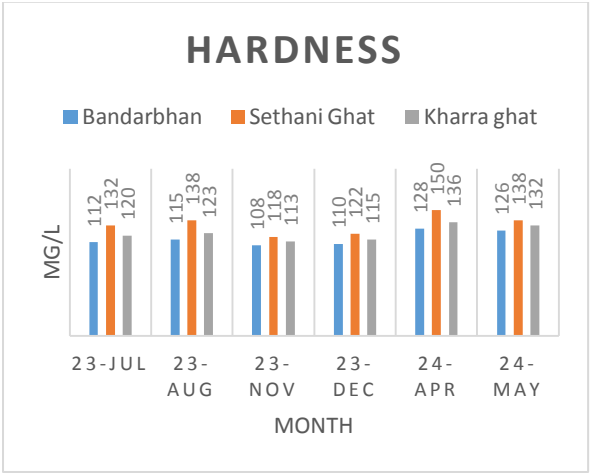

Fig 17 Hardness of water in each station in Narmadapuram

Lowest value of hardness 108mg/l is recorded at Bandrabhan (site:1) in the month of December 2023 and the highest value of hardness 150 mg/l has been observed at Sethanighat in the month of August 2023.

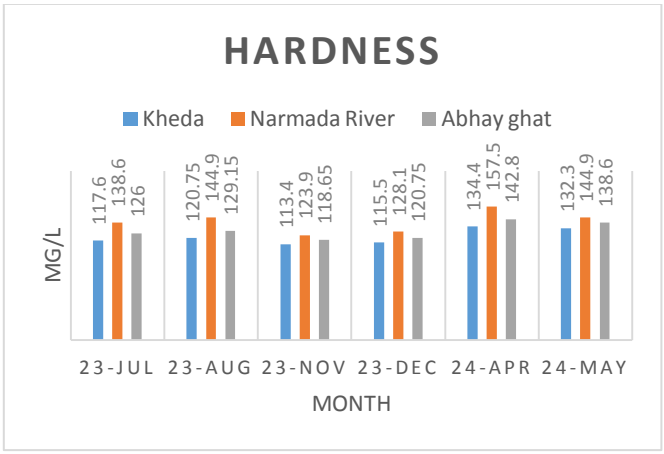

Fig 18 Hardness of water in each station in Omkareshwar

Lowest value of Hardness 113.4 mg/l is recorded at Kheda(site:1) in the month of December 2023 and the highest value of Hardness 157.5 mg/l has been observed at Narmada Ghat in the month of August 2023.

WATER QUALITY INDEX

The WQI has been calculated by using the standards of drinking water quality recommended by the World Health Organization (WHO), bureau of Indian Standards (BIS) and Indian Council for Medical Research (ICMR). The weight arithmetic index method (Brown et. al., 1970) has been used for the calculation of WQI of the water body. WQI has been calculated based on 10 selected physico-chemical parameters (given in table) for the all the six samples.

Table 1 Standard WQI

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

Table 2 Calculation of WQI of Bandarbhan for July 23

Parameter	Standard Limit (BIS)	standard	ideal	Weight (W)	july	qi	wq
Temperature	27	27	26		28	0.00	0
Turbidity	5 NTU	5	0	0.218	0	0.00	0.00

Total Hardness	200 mg/L	200	0	0.005	112	56.00	0.31
pH	6.5-8.5	8.5	7	0.128	7.3	20.00	2.57
Conductivity	250 uMhos/cm	250	0	0.004	178.6	71.44	0.31
TDS	500 ppm	500	0	0.002	176	35.20	0.08
Chloride	250 mg/L	250	0	0.004	10.46	4.18	0.02
``Dissolved Oxygen (DO)	5 mg/L	5	40	0.218	7.6	92.57	20.21
BOD	3 mg/L	3	0	0.364	1.1	36.67	13.34
COD	20 mg/L	20	0	0.055	17	85.00	4.64
Total Coliform	0 MPN/100ml	0	0	0	24	0.00	
				43			**41.47**

Where,

$$qi = \frac{Observed\ value - Ideal\ value}{(Standard\ value - ideal\ value)}$$

w= weighted average

$$\text{WQI Index} = \sum \frac{w * qi}{w}$$

$$\text{WQI Index} = 41.47$$

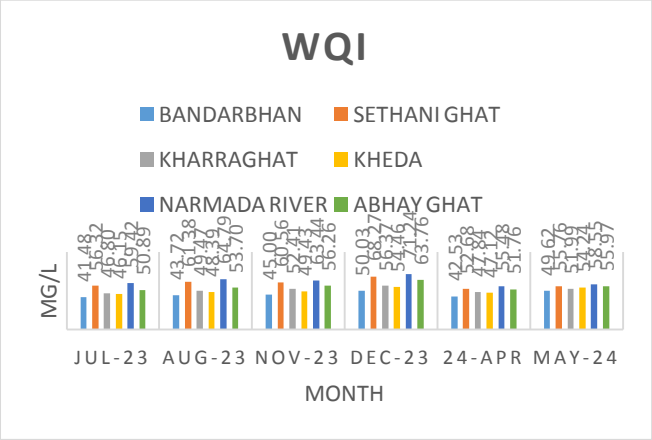

Fig 19 WQI for each station

Table 3 WQI For each station

STATIONS	**AVERAGE WQI**	**Water quality status**
BANDARBHAN	45.40	good water quality
SETHANI GHAT	59.16	poor water quality
KHARRAGHAT	50.81	good water quality
KHEDA	49.96	good water quality
NARMADA RIVER	62.15	poor water quality
ABHAY GHAT	55.39	poor water quality

CONCLUSION

The environmental assessment of Narmada River water at pilgrim places between Hoshangabad and Omkareshwar revealed significant variations in water quality across different locations and seasons. The study analyzed key physico-chemical and biological parameters, indicating that sites exposed to higher urban activity and untreated sewage discharge exhibited greater pollution levels.

Among the analyzed sites, Bandrabhan (Site 1) showed the best water quality, adhering to BIS and WHO standards, likely due to minimal anthropogenic disturbances. In contrast, sites like Sethanighat and Narmada Ghat exhibited poor water quality, characterized by high chloride, COD, total hardness, and total alkalinity, coupled with low dissolved oxygen levels. These results suggest that human activities, including direct waste discharge and urban runoff, significantly impact river water quality.

The Water Quality Index (WQI) analysis further supports these findings, categorizing Bandrabhan, Kharraghat, and Kheda as having "good water quality," whereas Sethanighat, Abhay Ghat, and Narmada River

were classified as having "poor water quality." The seasonal variations also highlight the influence of monsoons and human activities on water quality fluctuations.

To mitigate the degradation of the Narmada River, urgent measures such as improved sewage treatment, strict industrial effluent regulations, and public awareness campaigns should be implemented. Sustainable water resource management strategies are essential to preserving the ecological and social value of the river for future generations.

FUTURE SCOPE

The findings of this study highlight the need for continued research and sustainable management of the Narmada River water quality. Future research and policy actions can focus on the following aspects:

- Long-Term Monitoring: Establishing a continuous water quality monitoring system with advanced real-time sensors can help detect pollution trends and seasonal variations more accurately.
- Advanced Pollutant Analysis: Future studies can include a broader range of pollutants, such as heavy metals, microplastics, and emerging contaminants like pharmaceuticals and pesticides, to assess their impact on river health.
- Impact of Climate Change: Investigating the influence of climate change on river hydrology, including changes in water temperature, dissolved oxygen levels, and pollutant dispersion, will be crucial for adaptive management strategies.
- Biological Assessment: Including biological indicators such as plankton diversity, fish population studies, and microbial contamination assessments can provide a more holistic understanding of river health.
- Implementation of Pollution Control Strategies: Further research on the effectiveness of wastewater treatment technologies, nature-based solutions like constructed wetlands, and riverbank vegetation restoration can help mitigate pollution.
- Community Engagement and Policy Development: Strengthening awareness programs and community participation in river conservation initiatives can enhance public responsibility. Additionally, policymakers can use study findings to implement stricter regulations on industrial and domestic waste disposal.

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