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*Original Article*

# Assessment of Water Quality and Pollution Impact on the Chambal River at Nagda, Madhya Pradesh: A Physicochemical and WQI Analysis

**Virendra Kushwah, Bhawna Srivastava, Reddy P. B.***

*[1,3]Department of Zoology. Government PG College.Ratlam.M. P*
*[2]Department of Zoology, DAV College. Kanpur. U.P*

## ABSTRACT
The Chambal River, a vital freshwater resource in central India, faces significant pollution challenges due to industrial and municipal effluents. This study evaluates the physicochemical parameters of water quality and computes the Water Quality Index (WQI) at three locations near Nagda—Methwasa (reference site), Juna Nagda (point source), and Parmarkheri (downstream). The objective was to assess the extent of pollution and its ecological implications while providing actionable recommendations. Surface water samples were collected during the winter season of 2023 and analyzed for parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), nitrate, phosphate, and others. The WQI was calculated using established methods to integrate these parameters into a single indicator of water quality. The results revealed a WQI of 34.58 at Methwasa, indicating good water quality, while Juna Nagda and Parmarkheri exhibited WQI values of 444.04 and 235.22, respectively, categorizing them as "Very Bad." Elevated levels of EC, nitrate, phosphate, and chloride were observed at the polluted sites, exceeding WHO and CPCB standards. The findings emphasize the detrimental impact of untreated effluents on the river's health, posing risks to aquatic life and human use. To mitigate pollution, the study recommends the installation of wastewater treatment facilities, strict regulatory enforcement, continuous monitoring, and public awareness campaigns. These measures are critical to restoring the ecological balance and ensuring sustainable water management in the region.
**Keywords**: Chambal River, Water Quality Index, industrial pollution, physicochemical parameters, wastewater treatment, ecological health.

## INTRODUCTION
Rivers are among the most vital freshwater resources, playing a crucial role in sustaining biodiversity, supporting human livelihoods, and maintaining ecological balance (Reddy, 2012, Mishra 2023). However, the increasing industrialization, urbanization, and agricultural expansion in recent decades have severely compromised the quality of these water bodies worldwide (Reddy, P. and Rawat, 2013, Srivastava, B., and Reddy, P. B. (2020). The Chambal River, a major tributary of the Yamuna River, flows through the northern and central parts of India and is recognized for its ecological and cultural significance. Despite its importance, the river faces persistent threats from untreated industrial discharges and municipal wastewater, particularly in regions like Nagda, Madhya Pradesh, where industrial activity is concentrated.

Water quality is a multifaceted issue that affects not only aquatic ecosystems but also public health and socio-economic development (Sahoo and Goswami (2024). Physicochemical parameters such as pH, electrical conductivity (EC), dissolved oxygen (DO), and nutrient concentrations serve as critical indicators of water quality, reflecting the impact of natural and anthropogenic activities. Several studies have highlighted the pollution levels in Indian rivers, linking them to declining fish populations, contamination of drinking water supplies, and disruption of aquatic habitats (Singh et al 2022). For instance, studies on the Ganga and Yamuna rivers reveal significant correlations between industrial effluents and deteriorating water quality (Dwivedi et al., 2017; Shukla et al., 2019, Habibu et al 2025). However, limited research has focused on the Chambal River, particularly in pollution hotspots like

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Nagda. The Chambal River, designated as a National River Sanctuary for its rich biodiversity, including gharials, turtles, and river dolphins, is particularly vulnerable to pollution. The discharge of untreated effluents from industries such as textiles, chemicals, and pharmaceuticals in Nagda has led to severe ecological degradation. Earlier research by Singh et al. (2021) emphasized the accumulation of heavy metals in the sediments of the Chambal River, correlating it with industrial discharges. Similarly, Mishra et al. (2020) investigated the declining water quality downstream of urban centers but lacked a comprehensive analysis of the specific contribution of industrial effluents in Nagda. The present study addresses this gap by evaluating the water quality at three strategic locations—Methwasa (upstream reference site), Juna Nagda (point source of pollution), and Parmarkheri (downstream). The Water Quality Index (WQI), a widely used tool for assessing overall water quality, is employed to provide a simplified and comprehensive evaluation of the river's health. By integrating multiple physicochemical parameters, the study seeks to determine the extent of pollution and its implications for ecological and human health. The need for this study arises from the growing recognition of freshwater pollution as a global crisis and its specific relevance to the Chambal River. Understanding the pollution dynamics in Nagda is essential for formulating effective mitigation strategies and guiding policy interventions. The findings will also contribute to the broader discourse on sustainable water management, highlighting the need for stricter regulatory enforcement, advanced wastewater treatment technologies, and community participation in river conservation efforts. For that reason, this study aims to bridge the knowledge gap in understanding the pollution dynamics of the Chambal River at Nagda, providing evidence-based recommendations to restore its ecological integrity and ensure the sustainable use of its resources.

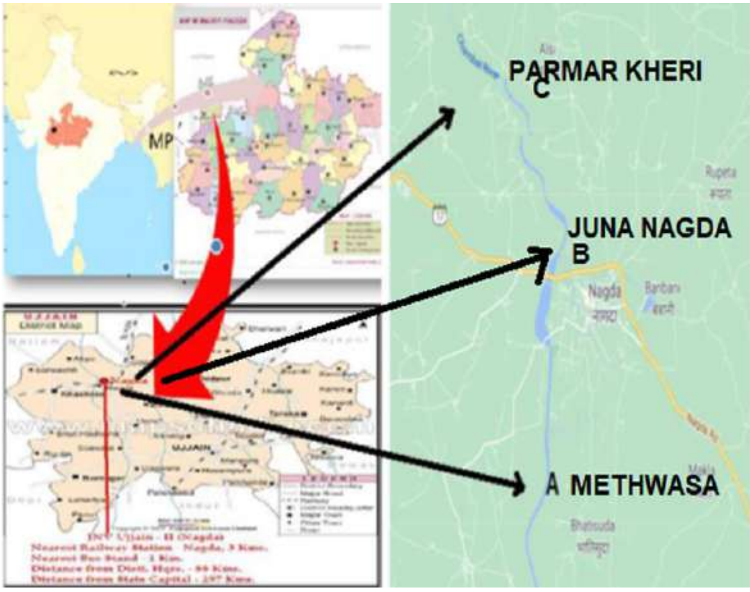
## MATERIALS AND METHODS:

**Study Area:** The Chambal River is a significant tributary of the Yamuna River, flowing through Rajasthan, Madhya Pradesh, and Uttar Pradesh. Known for its rich biodiversity and original stretches, the river faces severe pollution challenges in industrialized zones. Nagda, located in Madhya Pradesh, is a critical pollution hotspot due to the discharge of untreated industrial and municipal effluents. The study area includes three strategic locations along the Chambal River:

**Methwasa** (Upstream Reference Site): This site is located upstream of Nagda and serves as a baseline for comparison, being relatively unaffected by industrial or urban discharges.

**Juna Nagda** (Point Source of Pollution): Situated near industrial units, this site receives direct discharges from textile, pharmaceutical, and chemical industries, making it the primary focus for assessing pollution.

**Parmarkheri** (Downstream): Located downstream of Juna Nagda, this site reflects the cumulative impact of pollutants from the upstream industrial and urban activities.



**Sample Collection:** Surface water samples were collected during the winter season of 2023 from the three study locations. Samples were collected in sterilized polyethylene bottles, ensuring minimal contamination during handling and transportation.

**Physicochemical Analysis:** Key water quality parameters were analyzed following standard methods prescribed by the American Public Health Association (APHA, 2017). Parameters analyzed include and Electrical Conductivity (EC), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Nutrients (Nitrate and Phosphate), Chlorides, Sulfates, and Total Hardness (TH).

**Water Quality Index (WQI) Calculation**

WQI was calculated using the weighted arithmetic index method to provide a comprehensive assessment of water quality. Each parameter was assigned a unit weight (Wn) based on its relative importance. The quality rating (Qn) was determined using the formula:

$$Qn = \frac{Vn - Vio}{Sn - Vio} x\ 100$$

Where:

Vn= Observed value

Vio= Ideal value

Sn= Standard permissible value

The WQI was computed using the formula:

$$WQI = \frac{\sum(Wn - Qn)}{\sum Wn}$$

**Statistical Analysis:** Data were expressed as mean ± standard error of the mean (SEM). Variations between sites were analyzed using regression and correlation analyses to evaluate relationships between physicochemical parameters and pollution sources. The chosen methods ensure accuracy and reliability in detecting pollution levels. By integrating physicochemical parameters with WQI, the study provides a holistic understanding of water quality and its implications for ecological and human health. This methodology is consistent with global standards for water quality assessment, facilitating comparisons with other polluted river systems.

## RESULTS:

**Physico-chemical analysis of surface waters:** The results of physico-chemical analysis of surface waters of Chambal River at Nagda during 2023 December at three different stations were summarised in the table 1. An assessment of physicochemical parameters along the Chambal River near Nagda revealed significant water quality deterioration downstream from Juna Nagda, a point source of pollution. Compared to the reference site (Methwasa), Juna Nagda and Parmarkheri exhibited elevated levels of key indicators such as electrical conductivity (EC), pH, dissolved oxygen (DO), and nutrient concentrations (nitrate, phosphate). EC values at Juna Nagda (1994.3 µmhos/cm) exceeded the permissible limit of 1500 µmhos/cm, indicating high salt content. Similarly, pH levels at Juna Nagda reached 8.8, surpassing the acceptable range of 6.5–8.5, suggesting chemical contamination. DO levels were significantly lower at Juna Nagda (4.12 mg/l), indicating high organic pollution and a stressed aquatic ecosystem. Nutrient levels were alarmingly high, with nitrate concentrations at Juna Nagda (105.6 mg/l) far exceeding the permissible limit. Total dissolved solids (TDS), total hardness (TH), chloride, and sulfate levels also showed significant increases downstream, further emphasizing the impact of untreated effluents. While water temperature variations were minimal, regression analysis indicated a slight positive correlation with local environmental conditions. These findings underscore the severe degradation of water quality in the Chambal River, rendering it unsuitable for domestic use and posing a significant threat to aquatic life. Urgent interventions are crucial, including the establishment of effective wastewater treatment systems, continuous monitoring programs, and strengthened policy frameworks to mitigate pollution and safeguard the ecological health of the river and its surrounding communities.

**Table 2. Physicochemical parameters that were determined at different study locations of Chambal River at Nagda. The mean ± SEM is used to express values. Signific. ant changes are signified by different marks ($p < 0.05$).**

| Parameters | Methwasa (Reference site) | Juna Nagda (Point Source) | Parmarkheri (Downstream) | ISO10500:12 BIS STANDARDS (1983) |
|---|---|---|---|---|
| Temp (0C) | 19.54 ± 0.22 | 20.3 ±0.2 | 20.27 ± 0.2 | ----- |

| | | | | |
|---|---|---|---|---|
| EC (μmhos/cm) | 890.2 ± 8.84 | 1994.3±8.5 | 1425.7 ± 10.6 | 1,500 (WHO 82004). |
| pH | 7.3 ± 0.14 | 8.8 ±0.2 | 7.9 ± 0.3 | 6.5-8.5 |
| Total Alkalinity (mg/l) | 184.6 ± 5.92 | 519.26 ±5.54 | 499.2 ±5.54 | 200-600 |
| DO | 6.9 ± 0.2 | 4.12±0.30 | 5.9 ±0.30 | 6.5-8.5 |
| TDS (mg/l) | 288.4 ± 4.1 | 1098.3 ±3.0 | 923.02 ±3.0 | 300-500 |
| TH (mg/l) | 194.2 ±2.8 | 586.2±8.9 | 213.5 ±9.9 | 200-300 |
| Nitrate ( NO3 ), mg/l | 78.2 ± 3.88 | 105.6 ± 4.2 | 86.6 ± 3.2 | 45 Max |
| Chloride (Cl) mg/l | 202.3 ± 3.8 | 1125.2±8.32 | 363.2 ± 8.3 | 250 |
| Phosphate (ppm) | 0.08 ± 0.01 | 1.88 ± 0.01 | 1.1 ± 0.01 | 0.06-1.0 |
| Sulphate ($SO_4$) mg/l | 148.2 ± 3.64 | 578.9 ±5.2 | 289.6 ± 4.8 | 250 |

Water temperature showed minimal variation, ranging from 19.54°C at Methwasa to 20.3°C at Juna Nagda. Regression analysis demonstrated a slight positive correlation ($R^2$ = 0.7192) between temperature changes and local environmental conditions, though variations remained within tolerable limits. These findings underscore the significant degradation of water quality in the Chambal River downstream of Juna Nagda. Elevated levels of EC, TDS, TH, and nutrients highlight severe contamination, rendering the water unsuitable for domestic use and posing risks to aquatic ecosystems. Most parameters exceeded CPCB and WHO thresholds, signaling urgent intervention requirements.

**Water Quality Index (WQI) Analysis**

The water quality analysis of three different stations during the study period were summarized in Table 2, 3 and 4. The water quality at three stations along the Chambal River near Nagda during the winter season of 2023 was assessed using the Water Quality Index (WQI), a simplified measure integrating multiple physicochemical parameters. At Methwasa, the reference site, the WQI was 34.58, categorized as "Good" according to WHO standards. This indicates relatively pristine water quality with minimal human impact. In contrast, Juna Nagda, a point source of pollution, exhibited an alarmingly high WQI of 444.04, classifying the water as "Very Bad." This severe deterioration is attributed to the direct discharge of untreated industrial and municipal wastewater, leading to elevated levels of pollutants like electrical conductivity, nitrate, phosphate, and chloride. At Parmarkheri, the downstream site, the WQI was 235.22, also categorized as "Very Bad," indicating continued water quality degradation due to cumulative impacts of upstream pollution. Elevated levels of total dissolved solids, hardness, and nutrients further suggest ongoing contamination and reduced ecological health in the river.

**Table.26. Calculation of water quality index (WQI) for Chambal River at Nagda (Methwasa (upstream) reservoir during December 2023**

| Parameter | Observed values (Vn) | Standard Values (Sn) | Ideal Values (Vio) | Unit weight (Wn) | Quality rating (Qn) | WnQn |
|---|---|---|---|---|---|---|
| pH | 7.3 | 8.5 | 7.0 | 0.219 | 20 | 4.38 |
| Electrical Conductivity (EC) μS $cm^{-1}$ | 890 | 300 | 700 | 0.0007 | -26 | -0.28 |
| Total Dissolved Solid (TDS)(mg/L) | 288 | 300 | 500 | 0.0010 | 412.1 | -0.212 |
| Total alkalinity (mg/L) | 184 | 200 | 600 | 0.002 | 31.125 | 0.832 |
| Total Hardness as CaCO3 (mg/L) | 194 | 120 | 180 | 0.0062 | 123.66 | 0.766 |

| | | | | | | |
|---|---|---|---|---|---|---|
| DO (mg/L) | 6.9 | 5 | 10 | 0.3723 | 38 | 14.14 |
| Chloride (Cl- ) (mg/L) | 203 | 250 | 300 | 0.0074 | -94 | 0.06956 |
| Nitrate ($NO^3$-N) (mg/L) | 78 | 10 | 45 | 0.0412 | 194.28 | -0.671 |
| Sulphate (SO4 2- ) (mg/L) | 148 | 120 | 180 | 0.01236 | 47.0 | 0.580 |
| Phosphate ($PO^4$-P) (mg/L) | 0.07 | 0.005 | 0.05 | 0.03 | 145 | 4.332 |
| | | | | $\sum wn = 0.69216$ | $\sum qn = 891.165$ | $\sum wnqn = 23.93656$ |
| **Water Quality Index** $WQI = \frac{-\sum qnWn}{\sum Wn} = \frac{23.93656}{0.69216} = 34.5824$ | | | | | | |

**Table.26. Calculation of water quality index (WQI) for Chambal River at Nagda (Juna Nagda, Point source) reservoir during December 2023**

| Parameter | Observed values (Vn) | Standard Values (Sn) | Ideal Values (Vio) | Unit weight (Wn) | Quality rating (Qn) | WnQn |
|---|---|---|---|---|---|---|
| pH | 8.8 | 8.5 | 7.0 | 0.219 | 46.66 | 10.21 |
| Electrical Conductivity (EC) µS $cm^{-1}$ | 1994 | 300 | 500 | 0.371 | 847 | 314.237 |
| Total Dissolved Solid (TDS)(mg/L) | 1098 | 300 | 500 | 0.0037 | 399 | 1.4763 |
| Total alkalinity (mg/L) | 519 | 200 | 600 | 0.002 | 75 | 0.15 |
| Total Hardness as CaCO3 (mg/L) | 586 | 120 | 180 | 0.0062 | 300 | 1.86 |
| DO (mg/L) | 4.3 | 5 | 10 | 0.3723 | -14 | -5.21 |
| Chloride (Cl- ) (mg/L) | 1125.3 | 250 | 300 | 0.0074 | 1750.6 | 12.95 |
| Nitrate ($NO^3$-N) (mg/L) | 105 | 10 | 45 | 0.0412 | 271.42 | 11.18 |
| Sulphate (SO4 2- ) (mg/L) | 579 | 120 | 180 | 0.01236 | 765 | 9.4554 |
| Phosphate ($PO^4$-P) (mg/L) | 1.8 | 0.005 | 0.05 | 0.03 | 3888.8 | 116.666 |
| | | | | $\sum wn = 1.06516$ | $\sum qn = 8329.48$ | $\sum wnqn = 472.9747$ |
| Water Quality Index $WQI = \frac{-\sum qnWn}{\sum Wn} = \frac{472.9747}{1.06516} = 444.04$ | | | | | | |

**Table.26. Calculation of water quality index (WQI) for Chambal River at Nagda (Parmarkheri, downstream) reservoir during December 2023**

| Parameter | Observed values (Vn) | Standard Values (Sn) | Ideal Values (Vio) | Unit weight (Wn) | Quality rating (Qn) | WnQn |
|---|---|---|---|---|---|---|
| pH | 7.9 | 8.5 | 7.0 | 0.219 | 60 | 13.14 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Electrical Conductivity (EC) µS $cm^{-1}$ | 1425 | 300 | 500 | 0.371 | 562.5 | 208.68 |
| Total Dissolved Solid (TDS)(mg/L) | 923 | 300 | 500 | 0.0037 | 311.5 | 1.15255 |
| Total alkalinity (mg/L) | 499 | 200 | 600 | 0.002 | 74.25 | 0.1495 |
| Total Hardness as CaCO3 (mg/L) | 213 | 120 | 180 | 0.0062 | 155 | 0.961 |
| DO (mg/L) | 5.9 | 5 | 10 | 0.3723 | 18 | 6.7014 |
| Chloride (Cl- ) (mg/L) | 363 | 250 | 300 | 0.0074 | 226 | 1.6724 |
| Nitrate ($NO^3$-N) (mg/L) | 86 | 10 | 45 | 0.0412 | 217.142 | 8.946 |
| Sulphate (SO4 2- ) (mg/L) | 289 | 120 | 180 | 0.01236 | 281.667 | 3.4814 |
| Phosphate ($PO^4$-P) (mg/L) | 0.09 | 0.005 | 0.05 | 0.03 | 188.8 | 5.664 |
| | | | | $\sum wn = 1.06516$ | $\sum qn = 2094.859$ | $\sum wnqn = 250.5483$ |
| **Water Quality Index** $WQI = \frac{-\sum qnWn}{\sum Wn} = \frac{2540.5483}{1.06516} = 235.22$ | | | | | | |

**DISCUSSION:** The results of our study on the water quality of the Chambal River at Nagda, based on physicochemical parameters and Water Quality Index (WQI), align with contemporary research assessing the impacts of pollution from industrial and municipal discharges on river systems in India and globally.

In our study, the WQI values for Methwasa (34.58), Juna Nagda (444.04), and Parmarkheri (235.22) indicate clear variations in water quality, with the upstream Methwasa site showing good water quality, while Juna Nagda (point source) and Parmarkheri (downstream) exhibited very poor water quality. This deterioration is attributable to the combined discharges from industrial and urban sources, which is consistent with findings from other studies that highlight the significant impact of anthropogenic activities on river water quality. For instance, a study on the Ganga River in Varanasi (Ganga et al., 2023) demonstrated how industrial discharges and untreated sewage substantially degrade water quality, especially during the monsoon and post-monsoon seasons. The high levels of parameters like Electrical Conductivity (EC), Total Dissolved Solids (TDS), and Nitrate ($NO_3^-$) in the Chambal River, particularly at Juna Nagda, mirror the findings from this study, where similar pollutants exceeded the permissible limits. Furthermore, the decline in Dissolved Oxygen (DO) levels at Juna Nagda and Parmarkheri, which is indicative of organic pollution, is in line with observations from Dudhganga River (Patil et al., 2022), where reduced DO levels were also linked to industrial effluents. The significant increase in nutrient concentrations, including nitrates and phosphates, in our study echoes findings from the Yamuna River (Singh et al., 2020), where high nutrient loads were linked to untreated sewage and agricultural runoff. This nutrient overload can contribute to eutrophication, leading to further deterioration of water quality, as observed in Parmarkheri, where phosphate levels were notably elevated. Sulphate ($SO_4^{2-}$) and Chloride ($Cl^-$) concentrations, which were also high in our study, have been similarly implicated in various river quality studies. For example, in Jamuna River, Bangladesh (Rahman et al., 2023), high chloride levels were associated with industrial and municipal discharges, which is consistent with the observed pollution at Juna Nagda in our study. These findings are consistent with the Narmada River (Sharma et al., 2021), where high sulphate and chloride concentrations were linked to industrial discharge. Our results reinforce the need for stringent pollution control measures, as highlighted in global studies. The WQI values from Juna Nagda and Parmarkheri stress the urgency of addressing untreated industrial effluent and urban waste disposal to preserve river ecosystems and public health. The elevated contamination levels at these sites call for enhanced wastewater treatment and regular monitoring, which aligns with recommendations from Mutangwi River, Zimbabwe (Moyo et al., 2021), where a similar approach was suggested to mitigate the impacts of industrial pollution. In conclusion, our study's results are consistent with contemporary research, further underlining the detrimental effects of industrial and municipal discharges on river water quality. These findings emphasize the importance of continuous monitoring, effective wastewater treatment strategies, and the enforcement of environmental regulations to improve the overall quality of the Chambal River and other similar water bodies globally.

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