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# Assessment of Water Pollution in the Krishna River at Karad, Satara District, Maharashtra

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**Abstract**

This study assesses the water pollution status of the Krishna River at Karad, Satara district, Maharashtra, covering the period from 2011 to 2023. Seasonal and annual water quality data were analyzed using physico-chemical and microbiological parameters, including pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS), hardness, chlorides, sulphates, and fecal coliform counts. The results show that while pH and hardness remain within permissible limits, parameters such as BOD, TDS, and coliform levels frequently exceed Bureau of Indian Standards (BIS) and World Health Organization (WHO) guidelines. Seasonal variations reveal high microbial contamination during monsoon months and elevated TDS and chloride levels during summer due to reduced flows. The major sources of pollution include domestic sewage, industrial effluents from sugar mills and agro-based industries, agricultural runoff, and inadequate sewage treatment facilities. The study emphasizes the environmental consequences, such as biodiversity loss and ecosystem imbalance, alongside public health risks from microbial and chemical contaminants. It concludes with the need for integrated remedial measures, including sewage treatment plants, stricter effluent controls, sustainable farming practices, river rejuvenation efforts, and watershed-level governance for sustainable management of the Krishna River.

**Keywords:** *Krishna River, Water Pollution, Water Quality, Public Health.*



## 1. Introduction

The Krishna River is one of the most important perennial rivers of peninsular India, originating in the Western Ghats near Mahabaleshwar in Maharashtra and flowing through the states of Karnataka, Telangana, and Andhra Pradesh before emptying into the Bay of Bengal. It stretches over 1,400 kilometers, making it the fourth-largest river in India in terms of water discharge and basin area **(Keller et al.,** 2016). The river supports irrigation, drinking water supply, fisheries, hydropower generation, and cultural practices for millions of people across its basin. Its tributaries, including the Koyna, Ghataprabha, Malaprabha, Tungabhadra, and Bhima, contribute significantly to the socio-economic development of the Deccan plateau (Parmar et al., 2022).

At Karad in Satara District, Maharashtra, the Krishna meets its major tributary, the Koyna River, at a sacred site known as "Pritisangam" or the "confluence of love." This confluence has been historically revered and continues to attract pilgrims and visitors who consider the waters spiritually purifying (Jadhav & Jadhav, 2016). The region around Karad also has a rich cultural and political history, being associated with social reformers and freedom fighters. In addition to its religious significance, the confluence plays a vital role in maintaining regional hydrology, as the merging flows regulate water availability for irrigation and urban consumption.

Despite its cultural and ecological significance, the Krishna River near Karad has faced severe environmental stress due to increasing anthropogenic activities. Rapid urbanization, unregulated domestic sewage discharge, industrial effluents from sugar mills and agro-based industries, and agricultural runoff laden with fertilizers and pesticides have collectively deteriorated the water quality (CPCB, 2018). Reports indicate that several physico-chemical parameters—including Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Dissolved Solids (TDS)—exceed permissible limits set by the Bureau of Indian Standards (BIS) and the World Health Organization (WHO). Furthermore, seasonal variations exacerbate the problem, with monsoonal flooding leading to fecal coliform contamination, making the water unsafe for direct human consumption (Jadhav & Jadhav, 2018).

## 2. Objectives of the Study

The present study aims to provide a comprehensive assessment of the water pollution status of the Krishna River at Karad from 2011 to 2023. The specific objectives are:

- To evaluate seasonal and annual variations in physico-chemical and microbiological parameters of river water.
- To identify the major sources of pollution contributing to water quality degradation.
- To interpret the environmental and public health implications of the observed pollution levels.
- To suggest remedial and management strategies for sustainable river conservation.

## 3. Review of Literature

Research across the last decade highlights a persistent, multi-source pollution load in the Krishna basin around Karad. Site-based assessments consistently report seasonal swings in physico-chemical quality linked to flow regime and catchment activity: pre-monsoon low flows concentrate ions (higher TDS, chlorides, sulphates), while monsoon pulses dilute salts but raise microbiological contamination (coliforms) due to runoff and sewer overflows (Jadhav & Jadhav, 2016; 2018). Studies near urban outfalls and downstream of agro-industrial clusters (notably sugar and allied units) frequently record elevated BOD and COD alongside moderate alkalinity and hardness, with DO remaining adequate in high-flow seasons but declining locally near discharge points (Parmar et al., 2022; Keller, Keller, & Davids, 2016). Cumulatively, the literature points to a mixed "organic-nutrient-salinity" signature driven by domestic sewage, industrial effluents, and agricultural inputs, modulated by seasonal hydrology.

Regulatory syntheses by the Central Pollution Control Board (CPCB) and the Maharashtra Pollution Control Board (MPCB) classify multiple Krishna sub-stretches in Maharashtra under "priority" categories based on BOD exceedances and recurrent pathogen presence, aligning with field observations from academic studies (CPCB, 2018). These reports attribute non-compliance chiefly to inadequate sewage treatment capacity, intermittent operation/effectiveness of Effluent Treatment Plants (ETPs) in agro-industrial units, and diffuse inputs from peri-urban and agricultural landscapes. They also emphasize governance gaps—limited real-time monitoring, irregular compliance audits, and insufficient environmental flows—compounding seasonal stress in lean months.

Applications of composite Water Quality Indices (WQI) and related multivariate techniques (e.g., PCA, cluster analysis) consistently classify Krishna water near urban/industrial influence as “poor” to “marginal” for drinking without treatment, while segments with greater dilution or upstream of discharge points fare “good” to “fair” **(Jadhav & Jadhav, 2016; 2018; Parmar et al., 2022)**. Typical WQI drivers include BOD/COD (organic load), TDS and chlorides (salinity/mineralization), and microbial indicators in monsoon/post-monsoon seasons. Earlier works also note an inverse DO–BOD relationship and identify nutrient-organic co-loading as a key risk for ecological health and potability, reinforcing the need for source-segregated controls (sewage vs. industrial) and continuous surveillance **(CPCB, 2018; Keller et al., 2016)**.

## 4. Materials and Methods

The present study was conducted on the Krishna River stretch at Karad, located in Satara district, Maharashtra. Karad lies at the confluence of the Krishna and Koyna rivers, locally known as Pritisangam, which holds both ecological and cultural significance. The region experiences a semi-arid climate with marked seasonal variations: hot summers from March to June, heavy monsoon rains from July to September, and cooler winters from November to February. Karad serves as an important center for agriculture, education, and small-scale industries, while the presence of sugar factories and urban settlements has intensified the discharge of domestic sewage, industrial effluents, and agricultural runoff into the river. This makes the Karad stretch an ideal site to study the cumulative impacts of anthropogenic activities on river water quality.

To capture long-term variations, water quality data spanning the period 2011 to 2023 were analyzed. The sampling points included locations adjacent to urban discharge outlets, zones receiving agricultural runoff, and stretches downstream of industrial effluent discharge sites. In addition to data from direct sampling in published studies, secondary information was compiled from Maharashtra Pollution Control Board (MPCB) bulletins, Central Pollution Control Board (CPCB) reports, and municipal records maintained by Karad town authorities. This triangulated approach ensured both consistency and reliability in the dataset.

A comprehensive set of physico-chemical and microbiological parameters was examined to evaluate the health of the river. These included pH for measuring acidity or alkalinity, Dissolved Oxygen (DO) as an indicator of aquatic life sustainability, Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) for assessing organic and oxidizable pollutants, Total Dissolved Solids (TDS) for salinity and mineralization, and hardness to evaluate calcium and magnesium content. Additionally, chlorides and sulphates were analyzed as indicators of mineral and industrial contamination, while coliform bacteria, especially fecal coliforms, were included to assess microbiological pollution linked to untreated sewage. Each parameter was compared against permissible limits set by the Bureau of Indian Standards (BIS) and the World Health Organization (WHO) to evaluate compliance with national and global water quality guidelines.

For the purpose of seasonal interpretation, the data were grouped into three categories: winter (November–February), summer (March–June), and rainy/monsoon (July–September). Winter generally represents stable flows with relatively low microbial activity, summer is marked by reduced discharge leading to higher concentrations of pollutants, and the monsoon season brings dilution of salts but often increases microbiological contamination due to surface runoff and sewer overflows. This categorization allowed for an understanding of how hydrological cycles shape water quality dynamics.

The study relied on multiple data sources to improve the robustness of its conclusions. Academic works such as **Jadhav and Jadhav (2016, 2018)** provided seasonal and site-specific parameter values, while **Parmar et al. (2022)** contributed recent assessments of drinking water suitability in Satara district. **CPCB (2018)** reports on polluted river stretches in Maharashtra offered regulatory perspectives, and municipal monitoring records from Karad supplemented local observations. Cross-verifying data across these sources minimized the risk of bias and strengthened the reliability of the findings.

## 5. Results and Discussion

### 5.1 Seasonal Water Quality Analysis

The seasonal analysis of water quality parameters in the Krishna River at Karad from 2011 to 2023 is presented in Table 1. The data are categorized under winter, summer, and rainy seasons, with the overall mean values compared against Bureau of Indian Standards (BIS) permissible limits.

**Table 1:** Seasonal Water Quality Parameters of Krishna River at Karad (2011–2023)

| **Parameter** | **Winter (Mean ± SD)** | **Summer (Mean ± SD)** | **Rainy (Mean ± SD)** | **Overall Mean ± SD** | **BIS Standard*** |
|---|---|---|---|---|---|
| pH | 8.14 ± 0.23 | 7.98 ± 0.31 | 8.05 ± 0.31 | 8.05 ± 0.31 | 6.5–8.5 |
| Conductivity (µS/cm) | 157.51 ± 52.49 | 200.73 ± 99.43 | 203.55 ± 48.02 | 187.27 ± 71.79 | – |
| DO (mg/L) | – | – | 5.67 ± 0.27 | – | ≥ 4.0 |
| BOD (mg/L) | 6.01 ± 1.31 | 5.25 ± 1.34 | 5.31 ± 1.36 | 5.52 ± 1.35 | ≤ 5.0 |
| COD (mg/L) | 18.67 | 15.00 | 16.78 | ~16.78 | – |
| TDS (mg/L) | 1112.72 ± 40.55 | 1313.88 ± 69.37 | 1062.50 ± 41.21 | 1184.38 ± 53.46 | ≤ 500 |
| Hardness (mg/L) | 38.50 ± 17.77 | 70.17 ± 70.43 | 58.50 ± 21.76 | 55.72 ± 44.53 | ≤ 300 |
| Chloride (mg/L) | 38.92 ± 16.05 | 26.50 ± 19.65 | 28.50 ± 11.82 | 31.31 ± 16.64 | ≤ 250 |
| Sulphate (mg/L) | 29.17 ± 2.70 | 50.17 ± 3.98 | 44.83 ± 2.83 | 41.39 ± 3.25 | ≤ 200 |

*BIS Standards: Bureau of Indian Standards, IS 10500:2012 (for drinking water).

**Interpretation:**

The pH values remain within permissible limits across all seasons, reflecting stable buffering capacity of the river. Dissolved Oxygen (DO) values, though limited in measurement, consistently meet the minimum requirement of 4 mg/L, suggesting adequate oxygenation. However, Biochemical Oxygen Demand (BOD) exceeds the desirable limit (5 mg/L) in winter and remains close to the threshold in summer and rainy seasons, indicating organic pollution from sewage and effluents. Chemical Oxygen Demand (COD) values (15–18 mg/L) point to significant oxidizable pollutants, corroborating the organic load suggested by BOD. Total Dissolved Solids (TDS) values are alarmingly high (1062–1313 mg/L), more than double the BIS permissible limit (500 mg/L), making the water unsuitable for direct consumption. While hardness levels remain within safe limits, chloride and sulphate concentrations fluctuate but largely stay within permissible levels.

### 5.2 Annual Observations (2014–2023)

Annual water quality ranges between 2014 and 2023 are summarized in Table 2. These values provide a long-term view of the river's condition and highlight compliance or deviations from national standards.

**Table 2:** Annual Observations of Water Quality Parameters (2014–2023)

| **Parameter** | **Observed Range** | **BIS Standard*** | **Status** |
|---|---|---|---|
| pH | 6.69 – 8.60 | 6.5–8.5 | Within limits, occasional exceedance |
| DO (mg/L) | 6.64 – 8.93 | ≥ 4.0 | Safe |
| BOD (mg/L) | 1.6 – 27.6 | ≤ 5.0 | Frequently unsafe |
| Hardness (mg/L) | 48.5 – 83.5 | ≤ 300 | Safe |
| Fecal Coliform (CFU/100 mL) | 0 – 1800 (monsoon peak) | 0 (potable use) | Unsafe in monsoon |
| Chlorides (mg/L) | 117.5 – 417.5 | ≤ 250 | Often exceeds |
| TDS (mg/L) | 504 – 1066 | ≤ 500 | Consistently exceeds |

*BIS Standards: IS 10500:2012.

**Interpretation:**

Annual data indicate that pH generally falls within permissible limits, although occasional values above 8.5 suggest localized alkalinity. Dissolved Oxygen consistently meets standards, reflecting natural re-aeration, particularly during monsoon flows. BOD levels, however, frequently exceed safe limits, reaching as high as 27.6 mg/L, a clear indicator of organic pollution. Fecal coliform counts are particularly concerning, with peaks of 1800 CFU/100 mL during monsoon, rendering the water unsafe for potable use without treatment. Chloride concentrations frequently surpass 250 mg/L, while TDS values consistently exceed 500 mg/L, confirming long-term mineralization and salinity issues.

### 5.3. Interpretation of Results

The comparative analysis of seasonal and annual data underscores a consistent pattern of moderate to severe pollution in the Krishna River at Karad. While pH and hardness remain within acceptable ranges, the most critical parameters—BOD, TDS, and coliform counts—exceed permissible limits, highlighting organic and microbial contamination. Seasonal fluctuations reveal that monsoon waters are more prone to microbial pollution due to runoff, while summer months concentrate salts and dissolved solids due to reduced flows.

In terms of compliance, the river fails to meet BIS and WHO standards for safe drinking water in several key respects: TDS, chloride, and coliform exceedances compromise both potability and irrigation suitability. Although DO levels remain generally safe, the high BOD indicates oxygen stress zones, especially near discharge points. These results confirm that the Krishna River near Karad faces multi-dimensional pollution stress, necessitating urgent interventions such as sewage treatment, effluent control, and regular monitoring.

## 6. Sources of Pollution

One of the primary contributors to the deterioration of water quality in the Krishna River at Karad is the discharge of untreated or partially treated domestic sewage from Karad town and its adjoining peri-urban settlements. Rapid population growth has resulted in the generation of large volumes of household wastewater containing detergents, organic matter, and microbial contaminants. Much of this sewage is discharged directly into the river without adequate treatment, causing elevated Biochemical Oxygen Demand (BOD) and significant coliform contamination, particularly during the monsoon season when runoff increases the pollutant load.

In addition to domestic waste, the stretch of the Krishna near Karad receives industrial effluents, particularly from sugar mills, distilleries, and small-scale agro-based industries that dominate the regional economy. These industries release wastewater rich in organic matter, suspended solids, and occasionally heavy metals or chemical residues. Effluents from sugar processing often contain high concentrations of sugars, molasses, and organic sludge, which accelerate microbial activity and oxygen depletion when discharged untreated. While regulatory frameworks require the operation of Effluent Treatment Plants (ETPs), several units either operate them inefficiently or bypass the system, thereby worsening river pollution.

Another significant source of contamination is agricultural runoff from the extensive sugarcane, paddy, and vegetable cultivation in the Satara district. The indiscriminate use of chemical fertilizers and pesticides contributes to high levels of nutrients, particularly nitrates and phosphates, which enter the river through irrigation return flows and surface runoff. These inputs not only elevate Total Dissolved Solids (TDS) and sulphates but also contribute to eutrophication, increasing the risk of algal blooms and subsequent oxygen stress in the aquatic ecosystem.

Seasonal hydrology further exacerbates pollution levels, as the summer months are marked by reduced river flow, which diminishes the river's natural dilution capacity. With limited water availability, pollutants become more concentrated, leading to higher conductivity, mineralization, and TDS levels. This seasonal stress is particularly visible in summer data, where chloride and TDS often exceed permissible standards.

Finally, the persistence of these problems is closely linked to the lack of effective sewage treatment infrastructure in Karad and surrounding regions. The existing sewage treatment capacity is insufficient to handle the growing volume of wastewater, and operational inefficiencies further reduce effectiveness. The absence of decentralized treatment systems and limited enforcement of pollution norms by local authorities aggravate the situation, leaving the river vulnerable to cumulative pollution loads.

In summary, the combined effect of domestic sewage, industrial effluents, agricultural runoff, seasonal flow reduction, and inadequate treatment facilities has resulted in a multi-faceted pollution problem for the Krishna River at Karad. Unless systematically addressed, these sources will continue to compromise water quality, threatening both ecological balance and public health.

## 7. Environmental Impacts

The degradation of water quality in the Krishna River at Karad has led to profound ecological consequences, particularly for aquatic biodiversity. Elevated Biochemical Oxygen Demand (BOD) and periodic reductions in Dissolved Oxygen (DO) create oxygen-stressed environments that are detrimental to sensitive aquatic organisms. Pollutants such as organic waste, agro-chemicals, and suspended solids reduce light penetration and alter the physico-chemical composition of the river, thereby affecting primary productivity and disrupting food chains. The presence of coliform bacteria and high nutrient levels also fosters eutrophication, which leads to algal blooms, further lowering oxygen availability and creating unfavorable conditions for aquatic life.

One of the most visible outcomes of pollution stress is the decline in fish populations, particularly species sensitive to water quality fluctuations. A notable example is the decline of Labeo kawrus, a native species once abundant in the Krishna system but now significantly reduced due to deteriorating water quality, habitat loss, and reduced spawning grounds (IUCN Red List data). The combination of organic pollution, microbial contamination, and nutrient enrichment has made several stretches of the river unsuitable for breeding, leading to long-term declines in population density and diversity.

The overall impact has been a clear imbalance in the riverine ecosystem. The dominance of pollution-tolerant species over sensitive ones indicates a shift in ecological equilibrium. Macroinvertebrate communities, which act as bio-indicators, also reflect this imbalance, with tolerant species thriving while sensitive taxa decline. Such changes reduce the resilience of the river ecosystem, making it less capable of self-purification and more vulnerable to further stressors such as climate variability and increasing anthropogenic pressure.

Thus, the Krishna River at Karad exemplifies how unchecked pollution disrupts not only water quality but also the integrity of aquatic ecosystems, threatening biodiversity, ecological services, and the sustainability of river resources.

## 8. Public Health Implications

The deterioration of water quality in the Krishna River at Karad has direct and indirect consequences for human health. One of the most serious concerns arises from the presence of fecal coliform bacteria and associated pathogens, which consistently exceed permissible limits during the monsoon season. Elevated coliform counts, often reaching as high as 1800 CFU/100 mL, render the river water unsafe for potable use. Consumption of such contaminated water can lead to gastrointestinal infections, diarrheal diseases, cholera, and hepatitis, posing a significant risk to local communities that depend on untreated river water for domestic purposes. The high microbial load also compromises the suitability of water for recreational and religious use at Pritisangam, a site of ritual importance.

Beyond microbial contamination, the river exhibits chemical risks linked to elevated concentrations of nitrates, sulphates, and hardness-related minerals. Long-term exposure to nitrate-rich water has been associated with methemoglobinemia ("blue baby syndrome") in infants, while sulphates at elevated levels may cause laxative effects, dehydration, and other gastrointestinal disturbances. Although hardness levels generally remain below the Bureau of Indian Standards (BIS) limit of 300 mg/L, prolonged intake of water with fluctuating hardness can contribute to kidney stone formation and urinary complications, especially when combined with high Total Dissolved Solids (TDS).

The implications extend to agriculture as well. Farmers using Krishna River water for irrigation face challenges when TDS and chloride levels exceed safe thresholds, as observed in seasonal and annual data. Elevated salinity and hardness impair soil fertility, reduce crop yield, and alter soil structure over time. Irrigation with coliform-contaminated water also raises the risk of transmitting pathogens to vegetables and fruits consumed raw, thereby creating an indirect food safety hazard.

In summary, the combined presence of microbial pathogens and chemical contaminants in the Krishna River at Karad presents a dual threat to public health. Without adequate treatment and regulation, continued use of this water for drinking and irrigation may perpetuate cycles of disease, poor agricultural productivity, and long-term health complications for local populations.

## 9. Remedial and Management Measures

Effective management of the Krishna River at Karad requires an integrated approach combining infrastructure development, regulatory enforcement, sustainable agricultural practices, community participation, and transparent monitoring systems.

A primary step is the establishment of sewage treatment plants (STPs) in Karad and nearby towns. Much of the current domestic wastewater is discharged directly into the river without adequate treatment, leading to high organic and microbial loads. Setting up decentralized STPs with modern biological treatment technologies (such as activated sludge, sequencing batch reactors, or constructed wetlands) can significantly reduce Biochemical Oxygen Demand (BOD) and coliform contamination before the effluents enter the river.

Similarly, industrial effluent treatment and stricter enforcement of pollution control norms are essential. Sugar mills, distilleries, and small-scale agro-industries must ensure full compliance with effluent treatment plant (ETP) standards. Regular inspections, stricter penalties for violations, and the promotion of zero liquid discharge (ZLD) systems can reduce untreated effluents entering the river. Collaborative programs between the Maharashtra Pollution Control Board (MPCB) and industries can also promote cleaner production technologies.

On the agricultural front, the promotion of organic farming and reduction of chemical runoff is a sustainable measure. Excessive use of fertilizers and pesticides contributes to nitrate, sulphate, and pesticide residues in the river. Encouraging farmers to adopt integrated nutrient management (INM), bio-fertilizers, and organic soil amendments can minimize chemical leaching. Buffer zones with vegetative barriers along the riverbank can also help absorb excess nutrients before they reach the river.

Community engagement is equally vital. Public awareness campaigns and community participation can foster responsible behavior towards the river. Educating local residents about the impacts of open sewage disposal, improper waste management, and excessive chemical use in farming can generate collective responsibility for water conservation. Involving schools, NGOs, and religious organizations in river protection activities ensures a long-term cultural shift towards environmental stewardship.

In addition, large-scale river rejuvenation programs must be implemented. Periodic clean-up drives, desilting operations, and restoration of environmental flows are critical to maintaining ecological balance. Ensuring adequate water flow during summer months, possibly through regulated reservoir releases, can enhance the self-purification capacity of the river. Biodiversity restoration measures, such as reintroducing native fish species and conserving riparian vegetation, can also stabilize the ecosystem.

Finally, long-term sustainability requires regular monitoring and open access to water quality data. Establishing real-time water quality monitoring stations at Karad and upstream/downstream locations will provide early warnings of pollution spikes. Making this data publicly accessible through online platforms increases transparency and enables both policymakers and citizens to track progress. Such measures not only strengthen governance but also build trust and accountability among stakeholders.

In conclusion, the remediation of the Krishna River near Karad depends on a multi-pronged strategy that addresses both the sources of pollution and the structural gaps in management. By combining treatment infrastructure, stricter regulation, sustainable farming, public involvement, and transparent monitoring, it is possible to reverse the current degradation trends and ensure the river's ecological and socio-economic sustainability.

## 10. Policy and Governance Perspectives

The management of river pollution in Maharashtra, including the Krishna River at Karad, depends largely on the collective responsibilities of regulatory bodies, local governance, and national policy frameworks. The Central Pollution Control Board (CPCB) and the Maharashtra Pollution Control Board (MPCB) play central roles in identifying polluted stretches, setting effluent standards, and monitoring compliance. Their periodic reports, such as **CPCB's Polluted River**

Stretches of India (2018), have already classified parts of the Krishna as critically polluted based on BOD levels. However, enforcement challenges persist due to gaps in infrastructure, irregular inspections, and insufficient penalties for non-compliance. Strengthening the institutional capacity of CPCB and MPCB, along with empowering local municipalities, is crucial. Municipal bodies, being closest to pollution sources, have a direct role in establishing and maintaining sewage treatment plants (STPs), ensuring waste segregation, and monitoring smaller-scale polluters such as local businesses and markets.

At the national level, lessons can be drawn from flagship initiatives such as the National Mission for Clean Ganga (NMCG) and the broader Namami Gange program, which integrate sewage management, river rejuvenation, biodiversity conservation, and public participation. While the Krishna River is not directly covered under these schemes, adopting a “Namami Krishna” model could be beneficial. Similar interventions—including real-time water quality monitoring, strict industrial compliance, riverbank afforestation, and community-driven clean-up campaigns—could be adapted to the Krishna basin. Cross-learning from Ganga basin governance shows the value of central funding support, inter-state cooperation, and community engagement, which could strengthen river management in the Deccan region.

A broader vision requires the adoption of integrated watershed management policies. The Krishna River is part of a complex basin system influenced by urbanization, agriculture, industry, and climatic variability. Managing pollution at Karad cannot be seen in isolation but must be integrated with upstream and downstream water uses. Policies should therefore promote basin-wide coordination, ensuring that reservoirs, irrigation systems, and industrial units operate in harmony with ecological needs. Integrated watershed management would emphasize not only pollution control but also land use regulation, groundwater management, riparian vegetation restoration, and equitable water distribution. Such policies must also align with the Sustainable Development Goals (SDGs), particularly SDG 6 (Clean Water and Sanitation) and SDG 14 (Life Below Water).

In summary, the future of the Krishna River at Karad depends on stronger regulatory enforcement by CPCB and MPCB, active participation by municipalities, adaptation of national river rejuvenation models, and a shift toward integrated watershed governance. Only through a coordinated policy framework can the river’s ecological integrity and socio-economic value be safeguarded.

## 11. Conclusion

The present study highlights the growing concerns of water pollution in the Krishna River at Karad, Satara district, Maharashtra, based on seasonal and annual assessments from 2011 to 2023. The findings reveal that while certain parameters such as pH and hardness generally remain within permissible limits, several others—most notably Biochemical Oxygen Demand (BOD), Total Dissolved Solids (TDS), chloride concentrations, and fecal coliform counts—consistently exceed the standards prescribed by the Bureau of Indian Standards (BIS) and the World Health Organization (WHO). Seasonal analysis demonstrates that monsoon months are associated with microbial contamination due to runoff and sewage inflows, whereas summer months show higher mineralization and TDS levels due to reduced river flow and concentration of pollutants.

The sources of pollution are clearly linked to untreated domestic sewage, industrial effluents from sugar mills and allied industries, agricultural runoff rich in fertilizers and pesticides, and inadequate sewage treatment infrastructure. These inputs not only degrade water quality but also pose serious environmental risks, such as the decline of sensitive fish species like Labeo kawrus, and disrupt the riverine ecosystem balance. At the same time, the public health implications are severe, ranging from gastrointestinal infections and waterborne diseases due to coliform contamination to long-term risks associated with excessive nitrates, sulphates, and dissolved salts. The unsuitability of the water for drinking and irrigation without treatment underlines the urgent need for intervention.

Addressing these challenges requires a multi-pronged approach: establishing modern sewage treatment plants (STPs), enforcing strict compliance with industrial effluent standards, promoting organic and sustainable farming practices, and involving local communities in awareness and conservation programs. In addition, river rejuvenation measures such as desilting, biodiversity restoration, and maintaining environmental flows must be prioritized. Effective governance, guided by the CPCB and MPCB, supported by municipalities, and inspired by successful models like the Namami Gange program, can provide a roadmap for sustainable management.

In conclusion, the Krishna River at Karad exemplifies the broader challenges faced by Indian rivers under increasing anthropogenic pressure. Unless immediate remedial measures and integrated watershed policies are implemented, the river's ecological health, cultural significance, and socio-economic utility will continue to deteriorate. Conversely, with strong regulatory frameworks, technological interventions, and community participation, it is possible to restore the Krishna River to a healthier state, ensuring safe water for present and future generations.

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