Analysis of Water Quality Index Assessment of the Pavana River due to Infrastructural Development Activities

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Abstract - Water is a vital natural resource that supports human survival, ecological balance, and economic development. However, rapid urbanization and infrastructural development have significantly impacted river water quality, particularly in developing regions. This study focuses on the assessment of the Water Quality Index (WQI) of the Pavana River flowing through the Pimpri-Chinchwad Municipal Corporation (PCMC) area over a period from 2019 to 2025. The analysis is based on physico-chemical parameters such as pH, turbidity, total dissolved solids (TDS), electrical conductivity (EC), chloride, hardness, iron, fluoride, and dissolved oxygen, obtained from Water Treatment Plant records and validated using standard methods. Two sampling locations, Ravet and Shivnegaon, were selected to represent high and low infrastructural activity zones respectively. The Weighted Arithmetic Index Method was used for WQI calculation. The results indicate significant spatial and seasonal variation in water quality, with higher pollution levels observed in urbanized regions, particularly during the monsoon season due to runoff and industrial discharge. The WQI classification ranges from good to very poor depending on location and season. The study highlights the direct influence of infrastructural development on water quality and emphasizes the need for sustainable management practices.

Keywords: Water Quality Index, Pavana River, Urbanization, Seasonal Variation, Pollution.

1. **INTRODUCTION** :

The present study is derived from the final year project report submitted at JSPM’s Rajarshi Shahu College of Engineering, Pune, which focuses on the assessment of water quality deterioration due to infrastructural development in the Pavana River basin. Rivers are fundamental freshwater resources that sustain ecological systems and human activities. However, increasing urbanization has led to severe degradation of river systems, especially in rapidly developing urban regions (Tyagi et al., 2013).

In India, rivers are subjected to multiple stress factors including domestic sewage discharge, industrial effluents, and construction-related runoff (Singh et al., 2015). The Pavana River, flowing through the PCMC region, has experienced significant environmental stress due to rapid industrialization and urban expansion over the last decade. These activities introduce pollutants such as suspended solids, heavy metals, and dissolved salts into the river system (Sharma & Kansal, 2011).

The Water Quality Index (WQI) is widely used as an effective tool to assess overall water quality by integrating multiple parameters into a single value (Brown et al., 1970). It simplifies complex datasets and helps policymakers understand pollution trends (Ramakrishnaiah et al., 2009).

This study aims to evaluate long-term water quality changes and identify the impact of infrastructural development using WQI analysis.

2. LITERATURE REVIEW :

The assessment of water quality using indices has evolved significantly over time. Early work by Brown et al. (1970) introduced the concept of Water Quality Index as a simplified method for representing complex water quality data. Later, Horton (1965) emphasized the importance of integrating multiple parameters for effective environmental monitoring.

Researchers such as Tyagi et al. (2013) reviewed different WQI models and concluded that WQI is an essential tool for water resource management. Similarly, Ramakrishnaiah et al. (2009) applied WQI to evaluate groundwater quality and found it effective in identifying pollution zones.

Singh et al. (2015) studied river water quality in India and reported that urbanization significantly increases parameters like TDS, turbidity, and chloride. Sharma and Kansal (2011) observed that industrial discharge contributes heavily to conductivity and heavy metal concentration.

In a study conducted by Sargaonkar and Deshpande (2003), it was found that seasonal variation plays a crucial role in determining water quality, with monsoon causing maximum fluctuations due to runoff. Tripaty and Sahu (2005) further highlighted that turbidity increases significantly during rainfall due to soil erosion.

Another study by Khan et al. (2003) demonstrated that WQI helps in identifying the suitability of water for drinking purposes. Meanwhile, Bhutiani et al. (2014) emphasized the role of anthropogenic activities in degrading river ecosystems.

Recent studies such as Uddin et al. (2021) have incorporated statistical tools along with WQI to improve accuracy. Similarly, Verma et al. (2020) suggested integrating GIS and machine learning techniques for better prediction of water quality trends.

Overall, the literature suggests that WQI is a reliable and widely accepted method for assessing water quality, and infrastructural development is a major contributor to water pollution.

3. STUDY AREA :

The Pavana River originates from the Western Ghats and flows through the Pimpri-Chinchwad Municipal Corporation region in Maharashtra. The study area includes both semi-urban and highly urbanized zones, making it suitable for analysing the impact of infrastructural development on water quality.

The river basin experiences a tropical monsoon climate with distinct seasonal variations. During the monsoon season, heavy rainfall increases river discharge, while in summer, reduced flow leads to higher pollutant concentration. The upstream region is relatively less affected and consists of natural vegetation, whereas the downstream region, particularly Ravet, is highly urbanized with dense residential and industrial development.

The selected sampling locations, Shivnegaon and Ravet, represent contrasting environmental conditions. Shivnegaon is a semi-urban area with limited industrial activity, whereas Ravet is a rapidly developing urban zone influenced by construction activities, industrial discharge, and urban runoff. This variation allows for a comparative analysis of pollution levels across different land-use patterns.

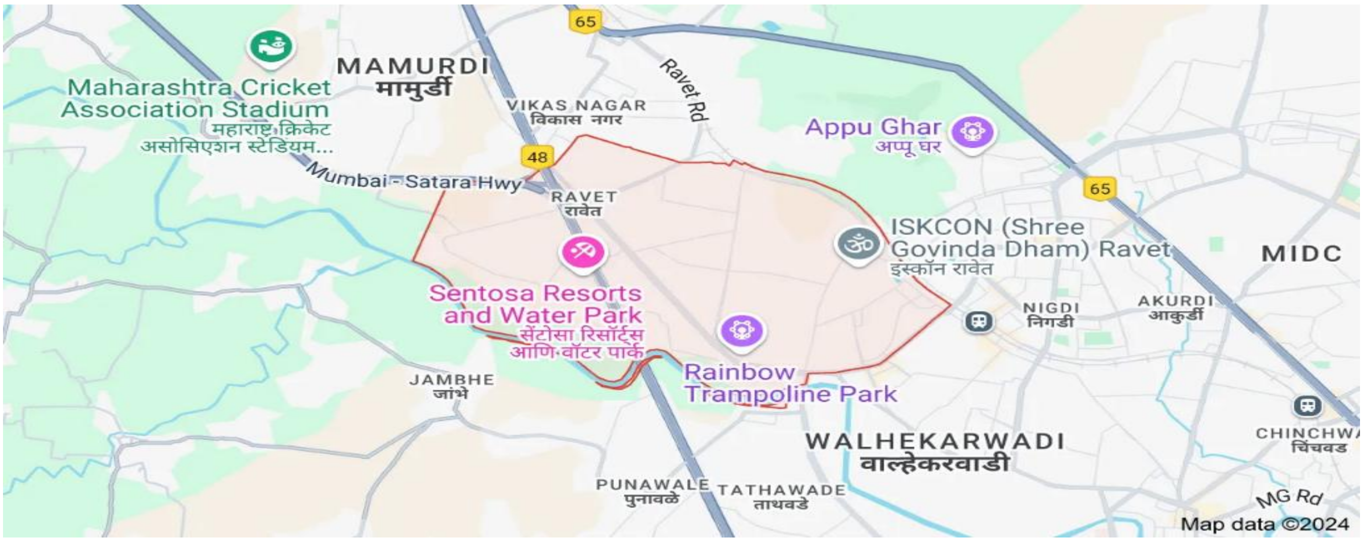


Fig3.1 Map of Ravet

Fig3.2 Map of Shivnegaon

4. Materials And Methods (Including WQI And Seasonal Analysis) :

The methodology adopted in this study is based on standard procedures recommended by APHA (2017) and BIS 10500:2012. Water quality data was collected from Water Treatment Plant records for the period 2019–2025 and analysed using physicochemical parameters such as pH, turbidity, TDS, EC, chloride, hardness, iron, fluoride, and dissolved oxygen.

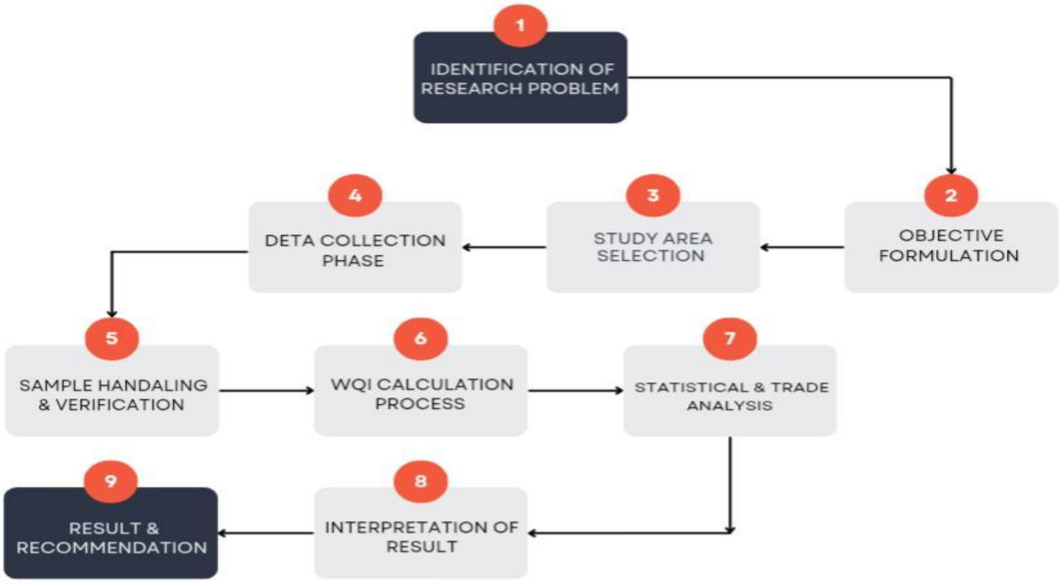


Fig 4.1 Methodology of project

Sampling was carried out at two locations, Ravet and Shivnegaon, representing high and low infrastructural activity zones. The analysis was performed using standard laboratory methods including electrometric method for pH, nephelometric method for turbidity, EDTA titration for hardness, and spectrophotometric methods for iron and fluoride.

4.1 Studied Parameters

4.1.1. pH - Indicates how acidic or alkaline the water is, affecting .corrosion potential and the survival of aquatic life.
4.1.2. Chloride (Cl-) - Shows the presence of dissolved salts, often increased by industrial discharge sewage, and road runoff.
4.1.3. Total Dissolved Solids (TDS) - Represents the total amount of dissolved inorganic and organic matter, affecting taste, hardness, and conductivity.

4.1.4. Electrical Conductivity (EC) - Reflects the ability of water to conduct electricity, directly linked to the concentration of dissolved ions.

4.1.5. Turbidity - Measures the cloudiness of water Caused by suspended particles, indicating runoff, erosion, or industrial waste contamination.

4.1.6. Iron (Fe) - Indicates the amount of dissolved iron, which can arise from industrial effluents, soil leaching, and corrosion of pipelines.

4.1.7. Fluoride (F) - Represents naturally occurring or industrially added fluoride levels, important for health but harmful when in excess.

4.1.8. Total Hardness - Measures calcium and magnesium ion concentration, indicating the mineral richness of water.

4.1.9. Manganese (Mn)- Shows the presence of dissolved manganese, commonly linked to industrial pollution, soil runoff, and groundwater interaction.

4.2 Calculation Of Water Quality Index (WQI) :

The Water Quality Index was calculated using the Horton`s Method (Horton et al., 1960), where each parameter is assigned a weight based on its importance. The quality rating is calculated by comparing observed values with standard permissible limits.

4.2.1 Definition

WQI is a numerical representation of water quality that combines multiple parameters into a single value.

4.2.2 Formula (Horton`s Method)

WQI is calculated as:

$$WQI=\sum(qn \times Wn) / \sum Wn$$

Where:

Wn = unit weight of n^th^ parameters

qn = quality rating of n^th^ parameters

4.2.3 Quality Rating (qn)

$$qn=[(Vn-Vid) / (Sn-Vi)]\times 100$$

Where:

Vn = observed value of n^{th} parameters

Sn = standard value of n^{th} parameters

Vid = ideal value for n^{th} parameters

parameters

4.2.4 Unite weight (Wn)

$$Wn= k/Sn$$

Where:

Sn = standard value of n^{th} parameters

k = Constant of proportionality and it is calculated by using following expression

$k = [1/(\sum(1/S_{n=1,2,..,n}))]$

4.3 Seasonal Variation Analysis :

Seasonal variation analysis was integrated into the methodology to understand the influence of climatic conditions on water quality. The data was categorized into three seasons: winter, summer, and monsoon. It was observed that during summer, reduced river flow leads to higher concentration of pollutants, while during monsoon, runoff from urban and industrial areas increases turbidity and dissolved solids. Winter season showed relatively stable and improved water quality due to lower anthropogenic influence.

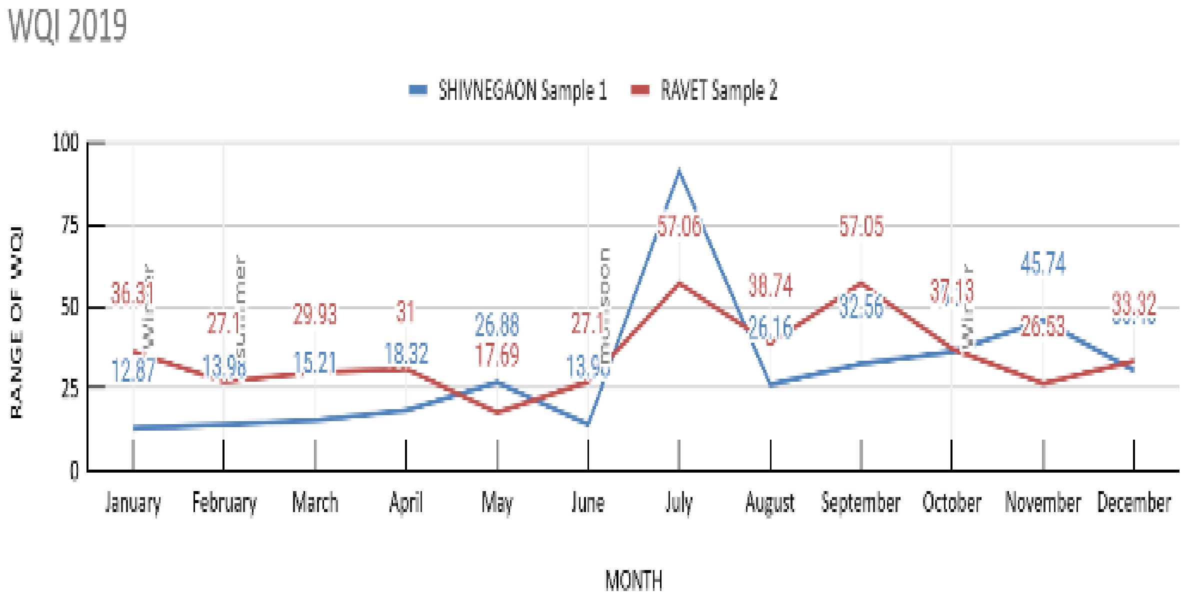
4.3.1.Key Seasonal Effects

Parameter	Winter	Summer	Monsoon
DO	High	Low	Moderate
Turbidity	Low	Moderate	High
TDS	Low	High	Moderate

4.3.2Interpretation

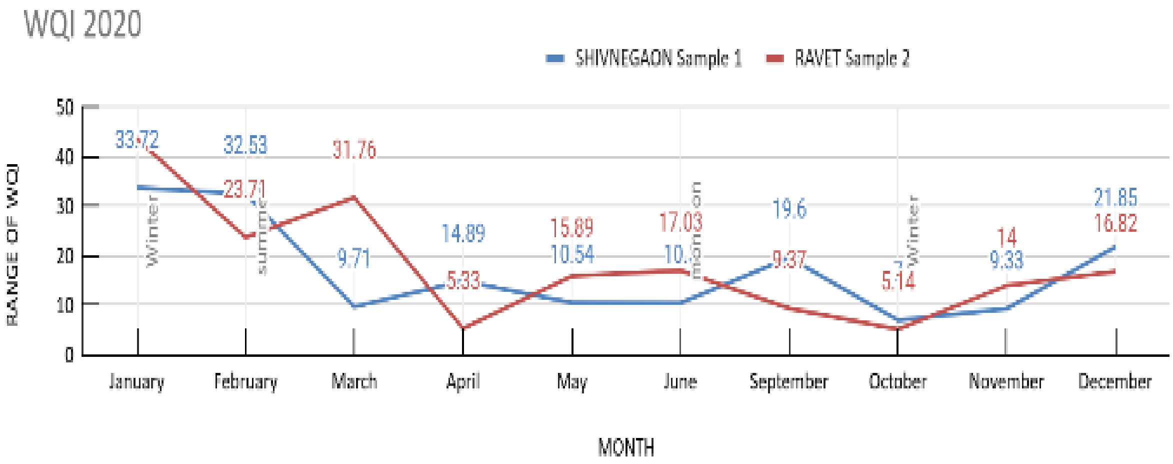
Seasonal variation plays a crucial role in determining pollution levels. Summer season shows the worst water quality due to concentration effects.

4.3.3 Graphs



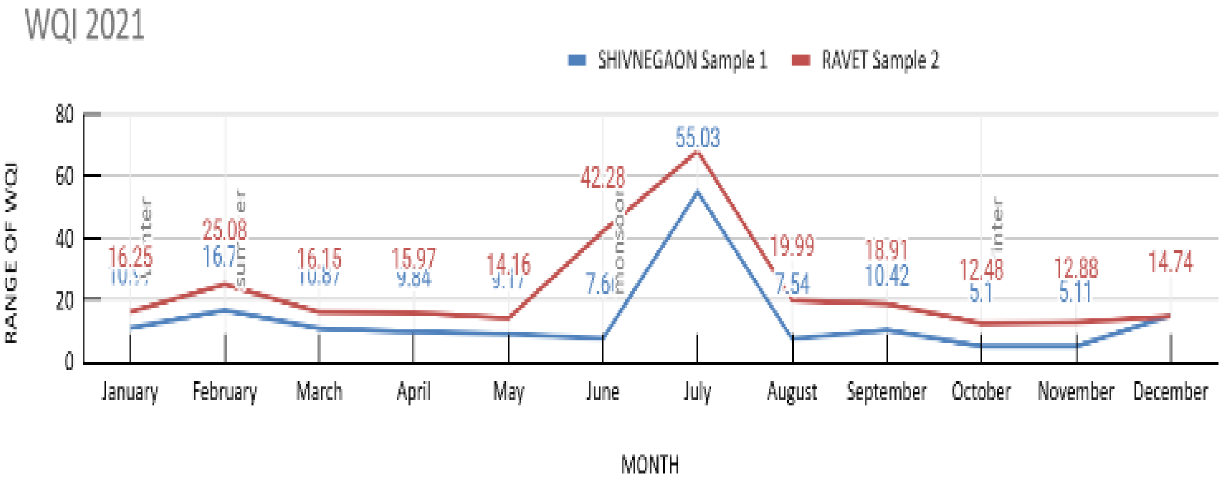
Graph 4.3.3.1 (WQI 2019) Months Vs Range of Water Quality Index

The graph for 2019 shows monthly variation of Water Quality Index (WQI) for both Shivnegaon and Ravet locations. The WQI values fluctuate throughout the year, with a noticeable peak during the monsoon months (July–August), indicating deterioration in water quality due to increased runoff and pollutant inflow. Ravet consistently shows higher WQI values compared to Shivnegaon, reflecting greater pollution due to urbanization. During winter months, the WQI values decrease, indicating relatively better water quality conditions.



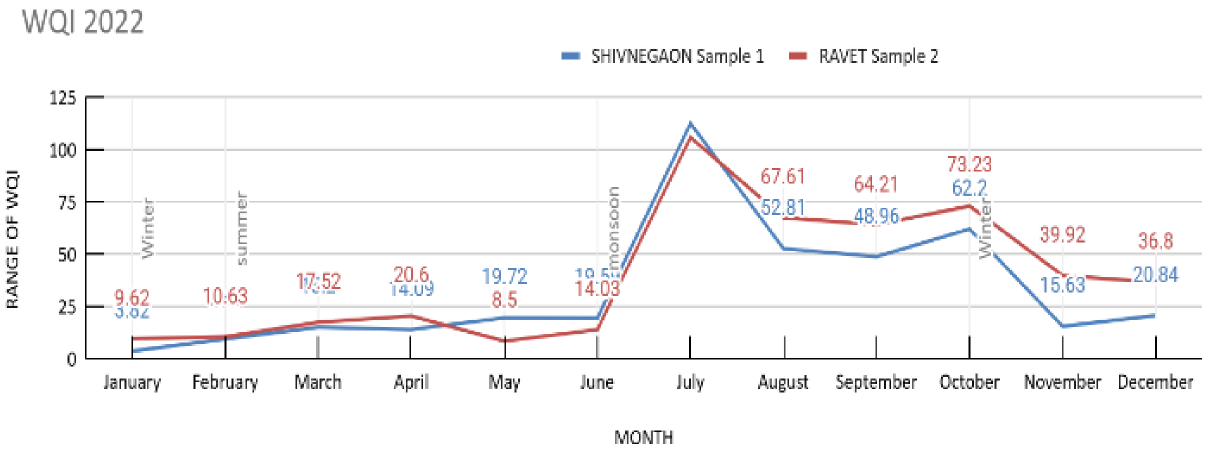
Graph 4.3.3.2 (WQI 2020) Months Vs Range of Water Quality Index

The 2020 graph indicates comparatively lower WQI values than 2019, suggesting slight improvement in water quality. However, seasonal variation is still evident, with higher values observed in the monsoon period. Shivnegaon shows relatively stable and lower WQI values, whereas Ravet experiences more fluctuations. The summer months show moderate WQI due to concentration of pollutants caused by reduced river flow.



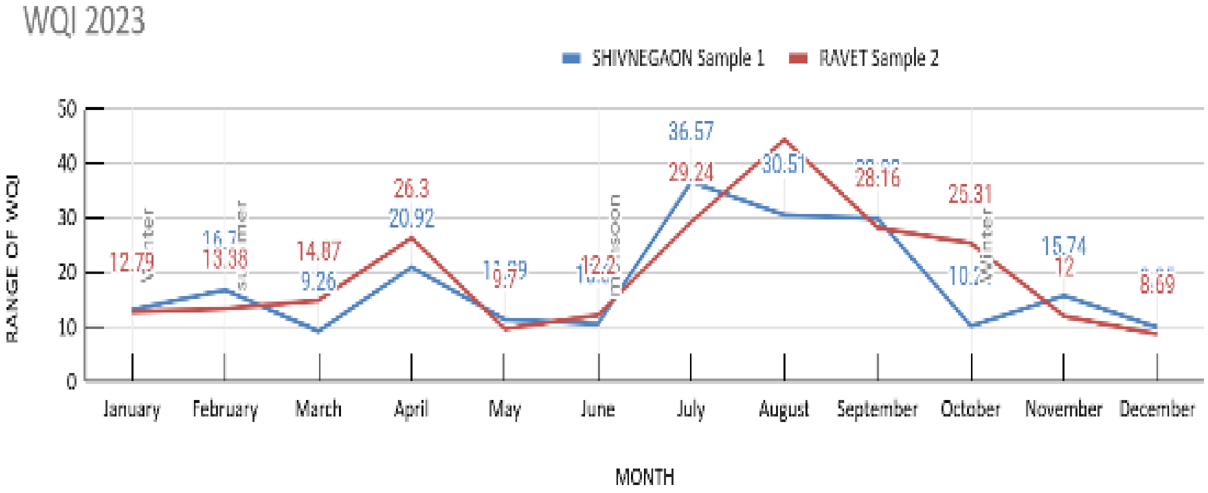
Graph 4.3.3.3 (WQI 2021) Months Vs Range of Water Quality Index

In 2021, the WQI trend again highlights a sharp increase during monsoon months, especially around July, where both locations record peak values. After monsoon, the WQI values gradually decline towards winter, indicating recovery in water quality. Ravet continues to show higher pollution levels than Shivnegaon. Overall, the graph reflects strong seasonal influence with monsoon being the most critical period for water pollution.



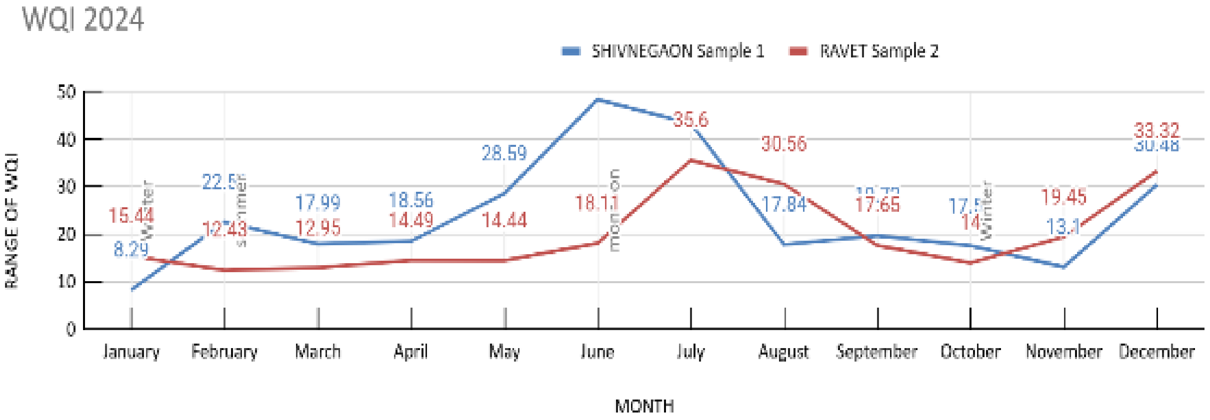
Graph 4.3.3.4 (WQI 2022) Months Vs Range of Water Quality Index

The 2022 graph shows a more pronounced increase in WQI values during mid-year (monsoon), with very high peaks compared to previous years. This indicates significant pollution load during this period. Both locations exhibit similar trends, but Ravet still records higher values. The early months (winter) show low WQI, suggesting better water quality, while summer shows a gradual increase due to pollutant concentration.



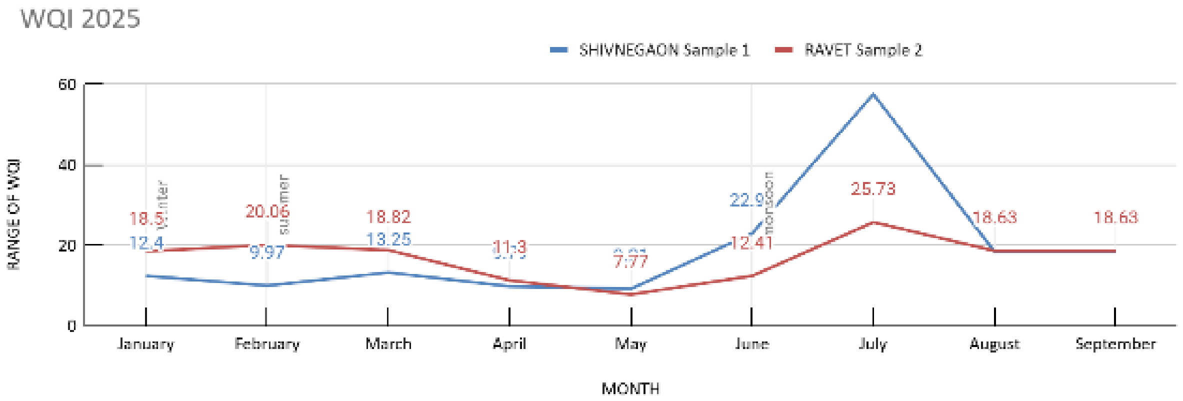
Graph 4.3.3.5 (WQI 2023) Months Vs Range of Water Quality Index

In 2023, the WQI values remain moderate for most of the year with a distinct rise during monsoon months. The graph shows smoother variation compared to previous years, indicating relatively controlled fluctuations. Shivnegaon maintains better water quality, while Ravet continues to show higher values. Post-monsoon, WQI values decline, indicating improvement in water conditions during winter.



Graph 4.3.3.6 (WQI 2024) Months Vs Range of Water Quality Index

The 2024 graph demonstrates similar seasonal behavior, with WQI values increasing during monsoon and decreasing in winter. A noticeable peak is observed around July, followed by a decline in subsequent months. Shivnegaon shows relatively lower WQI values, indicating better water quality, whereas Ravet shows higher fluctuations due to ongoing urban and infrastructural activities. Overall, the graph confirms consistent seasonal impact on water quality.



Graph 4.3.3.7 (Final Trend / Combined Observation) Months Vs Range of Water Quality Index

Although detailed plotting is not shown, Graph 4.3.3.7 represents the overall trend derived from all yearly graphs. It indicates that WQI values consistently peak during the monsoon season due to runoff carrying pollutants such as industrial waste, sewage, and construction debris into the river. Summer shows moderate WQI values because of reduced river flow and increased pollutant concentration. Winter season shows the lowest WQI values, indicating better water quality due to reduced external disturbances. Ravet consistently records higher WQI values than Shivnegaon, highlighting the strong impact of urbanization and infrastructural development on water pollution.

5. RESULTS AND DISCUSSION :

The results obtained from the WQI analysis indicate significant spatial and temporal variation in water quality. The graphical data from the final project report shows that WQI values fluctuate across different months and years, with higher values observed at Ravet compared to Shivnegaon.

The graph representing seasonal variation clearly indicates that WQI values peak during the monsoon season. This is due to increased surface runoff carrying pollutants such as construction debris, industrial waste, and domestic sewage into the river. The turbidity levels show a sharp rise during this period, which directly affects the WQI.

During the summer season, the graph shows moderate WQI values, particularly at Ravet, due to reduced river flow and increased concentration of pollutants. Parameters such as TDS, EC, and hardness show noticeable increases during this period. Shivnegaon, being less urbanized, shows relatively lower WQI values.

In the winter season, the graph indicates a decline in WQI values, suggesting improved water quality. This is attributed to reduced runoff and stabilization of river conditions. Dissolved oxygen levels are relatively higher, indicating better ecological conditions.

Spatial variation analysis shows that Ravet consistently exhibits higher WQI values due to dense industrial and residential development. Shivnegaon shows better water quality as it is less affected by anthropogenic activities.

6. RECOMMENDATION :

The study recommends implementing strict regulations on industrial discharge to reduce pollution load in the river. There is a need for proper wastewater management systems, including the construction of sewage treatment plants to treat domestic sewage before discharge. Sustainable urban planning should be adopted to minimize the impact of construction activities on water bodies. River restoration measures such as desilting and plantation along riverbanks should be encouraged. Advanced monitoring techniques such as IoT-based sensors and GIS mapping can be used for real-time analysis of water quality. Public awareness programs should be conducted to involve local communities in river conservation efforts. Effective policy implementation and regular monitoring are essential to ensure compliance with environmental standards.

7. CONCLUSION :

The study concludes that the water quality of the Pavana River is significantly affected by infrastructural development and urbanization. The WQI analysis reveals that water quality varies from good to very poor depending on location and season. The downstream region, particularly Ravet, shows higher pollution levels due to industrial discharge, construction activities, and urban runoff. Seasonal variation plays a crucial role, with monsoon season showing the worst water quality. The study highlights the need for continuous monitoring and effective management strategies to protect river water quality.

8. FUTURE SCOPE :

Future studies can focus on the integration of advanced technologies such as machine learning and artificial intelligence for predicting water quality trends. The inclusion of biological parameters such as BOD and COD can provide a more comprehensive assessment of water quality. Real-time monitoring systems can be developed to provide continuous data for better decision-making. Expansion of the study area to include more sampling locations will improve the accuracy of analysis.

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