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Water Quality Evaluation of Pawna River using QUAL2E Software

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Abstract

Pune, a rapidly expanding urban centre in Maharashtra, India, is experiencing significant industrial growth to cater to increasing regional demands while alleviating pressure on existing industrial hubs. The Pawana River, a key tributary of the Mula-Mutha River, flows through the Pimpri-Chinchwad Municipal Corporation area and serves as a vital water source for the city and its surrounding regions. However, over the past decades, anthropogenic activities such as industrial discharges and unregulated agricultural practices have adversely affected the river's water quality. This study investigates the water quality of the Pawana River using the QUAL2E model to analyze spatial variations in key parameters, including pH, alkalinity, hardness, turbidity, and chlorides. Laboratory analysis of samples collected from multiple locations along the river revealed that chemical parameters such as pH, alkalinity, hardness, and chlorides comply with IS 10500:2012 standards, indicating general suitability for consumption and ecological health. However, turbidity levels were consistently higher than permissible limits across all sampling locations, highlighting a critical concern. Elevated turbidity threatens aquatic ecosystems by inhibiting photosynthesis, disrupting habitats, and complicating water treatment processes, thereby posing risks to both ecological and public health. The results emphasize the necessity of identifying and mitigating sources of turbidity through targeted interventions and continuous water quality monitoring. The QUAL2E model proved effective in assessing the impacts of pollution sources and serves as a valuable tool for guiding sustainable water management strategies. This research underscores the urgency of proactive measures to preserve the ecological integrity and usability of the Pawana River.

Major Findings: *The study highlights that while the Pawana River's pH, alkalinity, hardness, and chloride levels comply with IS 10500:2012 standards, turbidity consistently exceeds permissible limits, posing ecological and public health risks. The QUAL2E model effectively identifies pollution impacts, underscoring the need for targeted interventions and continuous monitoring to address turbidity sources and ensure sustainable water quality management.*

Keywords: *Industrial Impact, Pawna River, QUAL2E Model, Water Pollution, Water Quality*

1.0 Introduction

The environmental impacts due to industrialization as well as agricultural growth have been overlooked and, regrettably, continue to be neglected in many regions worldwide. The exploitation of minerals and energy production has drastically transformed natural landscapes and altered water flow in the basins of major rivers[1]. Waste from factories and an industrial plant introduces hazardous substances into natural waterways, compromising water quality and its ability to sustain life[2]. Rapid population growth has led to increased human waste reaching surface waters or accumulating in the ground, immediately contaminating the environment

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and, over time, deteriorating aquatic ecosystems[3,4]. The flow is assumed to be in a steady state. The model simulates only the main stem of a river and does not simulate branches of the river system. It does not presently include an uncertainty component[5]. Water quality models have been used extensively in water resources management to improve understanding of the system and support decision-making[6,7]. The constituents included in the model are flow, temperature, BOD, DO, COD, pH, conductivity, and alkalinity[8]. To meet the demands of an ever-growing population, a heavily industrialized agricultural sector has emerged in both developed and developing countries, characterized by the extensive utilization of chemicals such as growth enhancers and insecticides[9]. Moreover, human activities, combined with deforestation and related practices, have a profound and often devastating impact on water quality[10]. With this, it is important to assess the water pollution levels, identification of areas violating standards, and examination of the behaviour of these pollutants by monitoring their concentration profiles in river water[11]. The Pawna River serves as one of the primary water sources for the cities of Pimpri Chinchwad and Pune in Maharashtra, India. Due growth of industries, coupled with inhabitants' growth as well as increased water demand, poses a significant pollution threat to the river[12,13]. The discharge of various pollutants, along with nutrients, can severely impact the river's water quality[14]. Given the importance of preserving the superiority of water of the river Pawna, given research work aims to assess the organic and inorganic sources of pollution, affecting the River of Pawna River and determine the quality of water by using QUAL2E Software.

2.0 Study Area

The origin of the Pawna River is in Lonavla in the Sahayadri Mountains and from there it flows approximately 60 kilometres and then it meets in Pune to Mula River. The study area focuses on the segment of the Pawna River near the Ravet Pumping Station, from where water is pumped for treatment to the Water Treatment Plant (WTP) in Nigdi, subsequently supplying water to the Pimpri Chinchwad Municipal Corporation (PCMC). The drainage area of the basin is located between Latitude 18° 33' 59" N and Longitude 73° 49' 59" E, from the western



Figure 1. Study area – Pawana River.

ghats which is about 6 km from south Lonavala with the river itself situated at an altitude of 650 meters. The Pawna River is a branch of the Mula Mutha River, which is one of the primary rivers flowing through Pune and Pimpri Chinchwad, Maharashtra. The Pawna Dam, constructed in 1972, plays a significant role in the region's water management. The dam is 1,329 meters long and 42.37 meters high, with a gross storage capacity of 0.24 cubic kilometres. It is located approximately 30 to 35 kilometres from Lonavala, contributing substantially to the water supply and irrigation in the region. The study was conducted at three strategic locations along the Pawana River (Figure 1), specifically situated at geographic coordinates 18° 38' 30" N, 73° 45' 03" E (NearMahadev Mandir, Punawale, Pune); 18° 38' 25" N, 73° 44' 53" E (NearPumpingStation, Ravet); and 18° 38' 24.5" N, 73° 44' 42" E (BelowSaintTukaram Bridge), ensuring comprehensive coverage of the river's key segments for water quality analysis.

3.0 Methodology

3.1 Field Investigations and Laboratory Analyses

Field investigations were conducted along a 6 km stretch of the Pawna River, encompassing diverse sampling locations to capture the variability in water quality. Key water quality parameters analyzed included pH, turbidity, hardness, chlorides, alkalinity, and conductivity. For 2 months water samples from various stations were taken and analyzed with the help of the standards for water and wastewater analysis. The QUAL2E model, developed by Brown and Barnwell (1987), was employed to simulate the water superiority in the Pawna River[15]. This model utilizes finite difference solutions to calculate up to 15 water quality components in the branch line system[16]. The software can manage various waste disposal charges, withdrawals, branch flows, inflows, and outflows[17,18]. Additionally, it determines the necessary dilution flows to reach specific DO levels. An initial stage by using QUAL2E involves dissociating the river range into segments with constant hydro-geometric characteristics[19,20]. Each segment must account for water flow balance, temperature balance, and material concentration balance. The one-dimensional advective-dispersive equation is calculated for steady-state conditions, assuming constant discharge, while allowing for temporal variations in temperature, wind, and light[21]. The entire length of the Pawna River, approximately 6 km near the Ravet Pumping Station, was divided into three sections, each with a computational length of 2 km. Data including discharge measurements and geometrical parameters of the river, were collected from August 2023 to October 2023.

a. pH Test: Power on the device and let it warm up. Immerse the pH electrode in a standard buffer solution. Adjust the temperature knob to match the solution's temperature. Set the pH knob to correspond with the buffer's pH. Rinse the electrode with distilled water and put it in a different buffer solution. If needed, fine-tune the pH control knob for precise calibration. Insert the electrode into the test solution and record the pH. Clean the electrode with distilled water between measurements (Figure 2). Repeat the steps to measure the pH of another solution (Table 1).

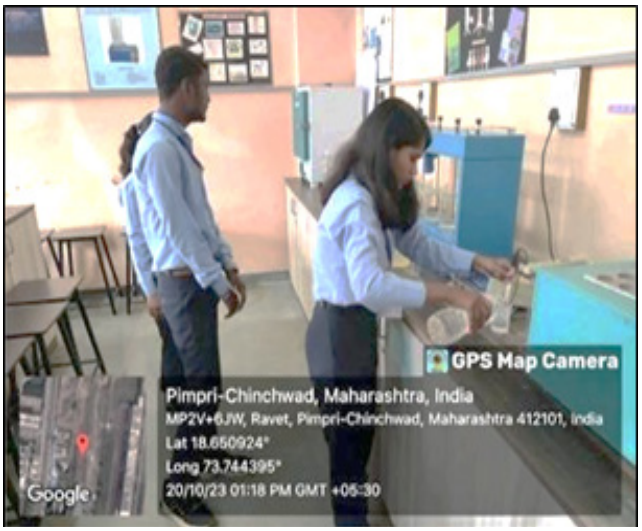


Figure 2. pH testing.

Table 1. pH - Water quality parameter at different locations of the Pawana River against IS 10500: 2012 Norms

Location Name	Tests	Sample Test- Day 1	Sample Test- Day 15	Sample Test- Day 30	Sample Test- Day 45	Norms by IS10500:2012
Location 1	pH Value	6.5 scale	6.8 scale	7 scale	7.9 scale	6.5 to 8.5
Location 2		7.1 scale	7.5 scale	8.9 scale	7.8 scale	6.5 to 8.5
Location 3		7.4 scale	6.9 scale	8 scale	6.8 scale	6.5 to 8.5

b. Alkalinity: Pour 50 ml of the water test sample into a conical flask and put in 2-3 drops of phenolphthalein indicator. If the solution stays colourless, move on to measure total alkalinity. If the solution turns pink, titrate with 0.1 N HCl until the pink colour fades to determine phenolphthalein alkalinity. Add 2-3 drops of methyl orange to the same sample and continue the titration until the yellow colour changes to orange to determine total alkalinity (Figure 3). Repeat the steps to measure the Alkalinity of another solution (Table 2).

c. Chlorides: Pour 50 ml of the water testing sample into a conical flask and add 2 ml of potassium chromate



Figure 3. Alkalinity test.

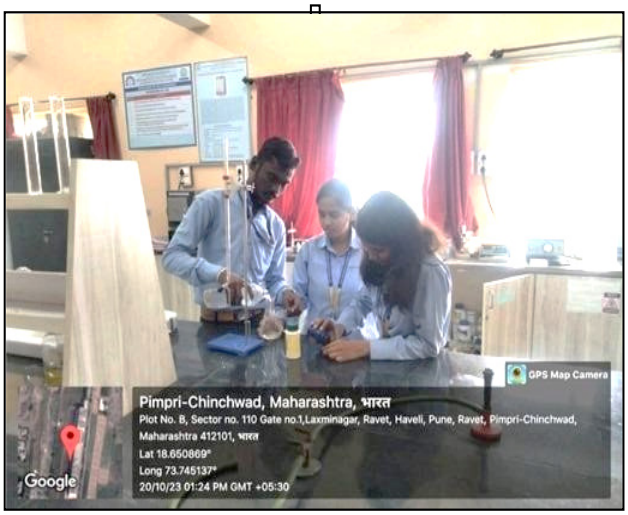


Figure 4. Chlorides test.

Table 2. Alkalinity - Water quality parameter at different locations of the Pawana River against IS 10500: 2012 norms

Location Name	Tests	Sample Test- Day 1	Sample Test- Day 15	Sample Test- Day 30	Sample Test- Day 45	Norms by IS10500:2012
Location 1	Alkalinity	253 ppm	190 ppm	180 ppm	172 ppm	30 to 400 ppm
Location 2		121 ppm	135 ppm	146 ppm	139 ppm	30 to 400 ppm
Location 3		156 ppm	126 ppm	145 ppm	130 ppm	30 to 400 ppm

Table 3. Chlorides - Water quality parameter at different locations of the Pawana River against IS 10500:2012 Norms

Location Name	Tests	Sample Test- Day 1	Sample Test- Day 15	Sample Test- Day 30	Sample Test- Day 45	Norms by IS10500:2012
Location 1	Chlorides	58 ppm	32 ppm	49 ppm	36 ppm	50 to 200 ppm
Location 2		35 ppm	46 ppm	52 ppm	48 ppm	50 to 200 ppm
Location 3		38 ppm	46 ppm	52 ppm	20 ppm	50 to 200 ppm

solution. Titrate with 0.02 N silver nitrate solutions until a reddish-brown colour forms (Figure 4) and record precise readings to determine the *chloride* concentration (Table 3).

d. Hardness: In an Erlenmeyer flask, dilute 25 ml of the sample to 50 ml with distilled water. Add 1 ml of buffer solution and two drops of the indicator solution. Titrate with a standard EDTA solution until the solution changes from wine red to blue (Figure 5). Record the volume of EDTA used to determine the total hardness (Table 4).

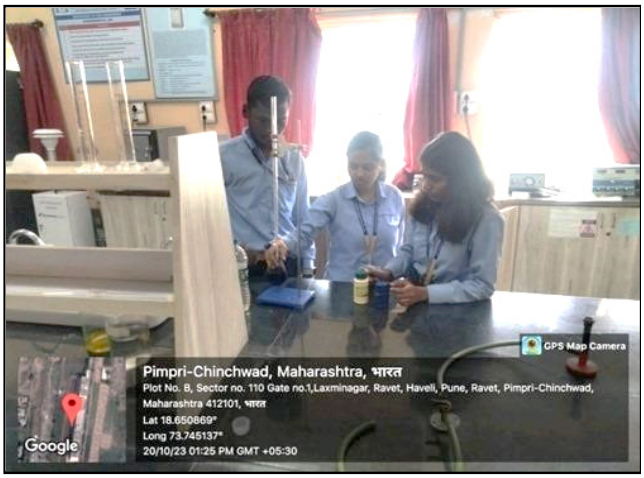


Figure 5. Hardness test.

e. Turbidity: Measure turbidity right away to prevent alterations due to temperature shifts or particle



Figure 6. Turbidity test.

Table 4. Hardness - Water quality parameter at different locations of the Pawana River against IS 10500:2012 Norms

Location Name	Tests	Sample Test- Day 1	Sample Test- Day 15	Sample Test- Day 30	Sample Test- Day 45	Norms by IS10500:2012
Location 1	Hardness	98 ppm	78 ppm	85 ppm	72 ppm	Below 200 ppm
Location 2		96 ppm	70 ppm	67 ppm	38 ppm	Below 200 ppm
Location 3		56 ppm	59 ppm	38 ppm	35 ppm	Below 200 ppm

Table 5. Turbidity - Water quality parameter at different locations of the Pawana River against IS 10500:2012 Norms

Location Name	Tests	SampleTest- Day 1	Sample Test- Day 15	Sample Test- Day 30	Sample Test- Day 45	Norms by IS10500:2012
Location 1	Turbidity	180 NTU	154 NTU	166 NTU	157 NTU	Below 5 to 15 NTU
Location 2		178 NTU	198 NTU	142 NTU	166 NTU	Below 5 to 15 NTU
Location 3		160 NTU	178 NTU	167 NT	128 NTU	Below 5 to 15 NTU

aggregation. Eliminate air bubbles using a partial vacuum, surfactant, ultrasonic bath, or heat. Avoid diluting the sample to preserve its original properties. Standardize the nephelometer Pour a well-mixed sample into a cell and degas if needed (Figure 6). Read the turbidity value from the instrument display (Table 5).

4.0 Result and Analysis

4.1 Introduction

The analysis of the Pawana River water across three different locations highlights significant compliance with IS 10500:2012 standards for pH, alkalinity, hardness, and chlorides, ensuring that the water is generally safe for consumption and ecological sustenance in these aspects. However, the consistently high turbidity levels across all samples present a notable concern. Elevated turbidity can have detrimental effects on both aquatic ecosystems and human health by obstructing sunlight penetration, impairing photosynthesis, and complicating water treatment processes. It is critical to identify the sources of turbidity and implement targeted interventions to mitigate its impacts. Further research and continuous

Table 6. Comparative analysis of water quality parameters at different locations of the Pawana River Against IS 10500:2012 Norms

Location Name	Tests	Sample Test- Day 1	Sample Test- Day 15	Sample Test- Day 30	Sample Test- Day 45	Normsby IS10500: 2012
Location 1	pH Value	6.5 scale	6.8 scale	7 scale	7.9 scale	6.5 to 8.5
	Alkalinity	253 ppm	190 ppm	180 ppm	172 ppm	30 to 400 ppm
	Turbidity	180 NTU	154 NTU	166 NTU	157 NTU	Below 5 to 15 NTU
	Hardness	98 ppm	78 ppm	85 ppm	72 ppm	Below 200 ppm
	Chlorides	58 ppm	32 ppm	49 ppm	36 ppm	50 to 200 ppm
Location 2	pH Value	7.1 scale	7.5 scale	8.9 scale	7.8 scale	6.5 to 8.5
	Alkalinity	121 ppm	135 ppm	146 ppm	139 ppm	30 to 400 ppm
	Turbidity	178 NTU	198 NTU	142 NTU	166 NTU	Below 5 to 15 NTU
	Hardness	96 ppm	70 ppm	67 ppm	38 ppm	Below 200 ppm
	Chlorides	35 ppm	46 ppm	52 ppm	48 ppm	50 to 200 ppm
Location 3	pH Value	7.4 scale	6.9 scale	8 scale	6.8 scale	6.5 to 8.5
	Alkalinity	156 ppm	126 ppm	145 ppm	130 ppm	30 to 400 ppm
	Turbidity	160 NTU	178 NTU	167 NT	128 NTU	Below 5 to 15 NTU
	Hardness	56 ppm	59 ppm	38 ppm	35 ppm	Below 200 ppm
	Chlorides	38 ppm	46 ppm	52 ppm	20 ppm	50 to 200 ppm

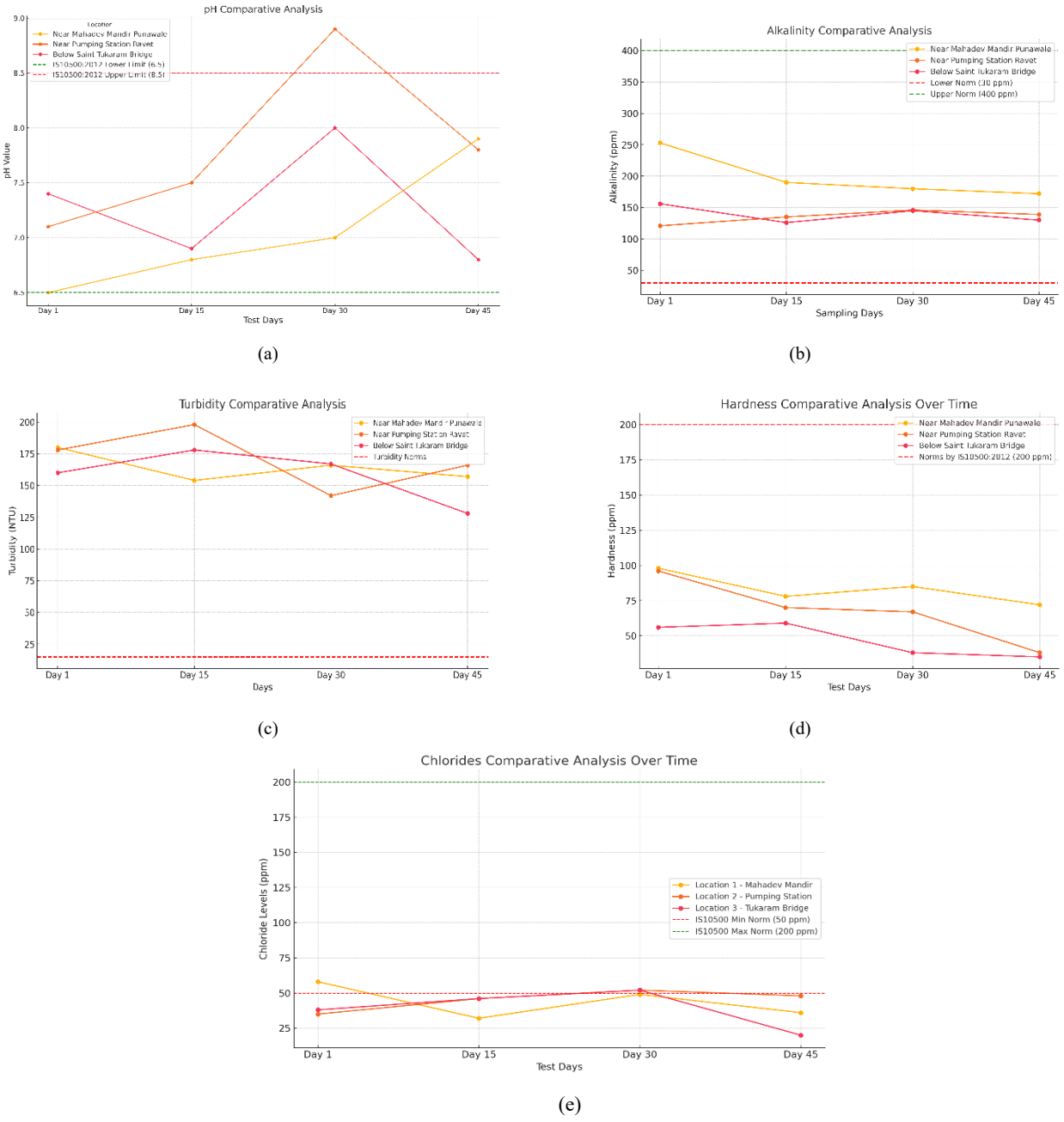


Figure 7. Comparative Analysis over Time **(a)** For pH, **(b)** For alkalinity, **(c)** For turbidity, **(d)** For hardness, and **(e)** For chlorides.

monitoring of the quality of water is essential for the Pawana River for a healthy ecosystem.

The water superiority parameters for the Pawana River were analyzed using the QUAL2E software at three distinct locations: Near Mahadev Mandir (Punawale), Near Pumping Station (Ravet), and Below Saint Tukaram Bridge. As per Table 6, the parameters studied include pH value, alkalinity, turbidity, hardness, and chlorides. These values were compared with the norms specified in IS 10500:2012 to assess compliance and identify areas of concern.

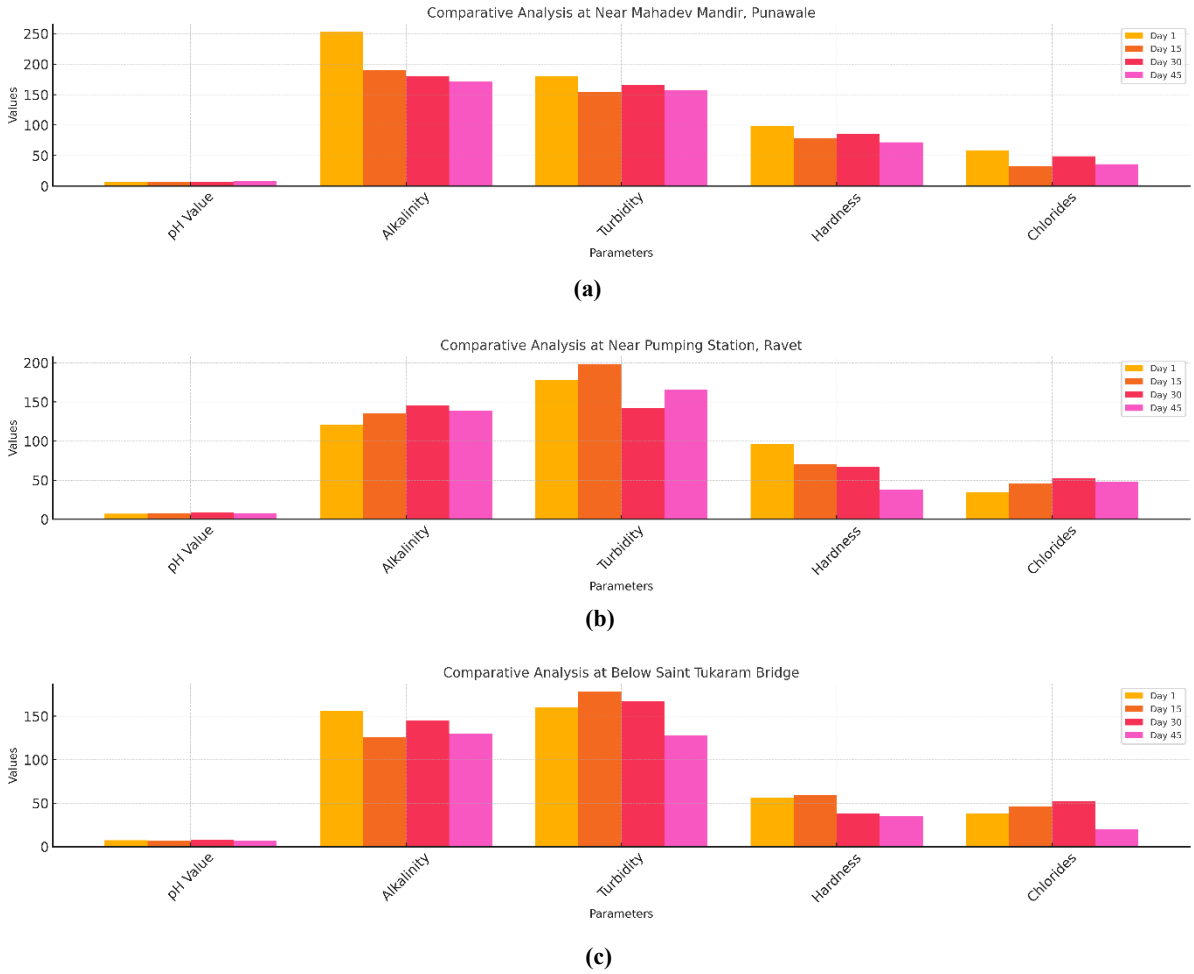


Figure 8. Comparative analysis w.r.t. parameters values **(a)** at Location 1 - Near Mahadev Mandir, Punawale, **(b)** at Location 2 – Near Pumping Station, Ravet, and **(c)** at Location 3 – Below Saint Tukaram Bridge.

Using the QUAL2E software, water quality at all three locations was analyzed and compared against the IS 10500:2012 norms. The analysis of pH values revealed that all locations generally fell within the permissible range, except for one sample from Location 2, which indicated potential alkalinity issues (Figure 7(a)). Alkalinity levels across all three locations were within acceptable limits, suggesting good buffering capacity throughout the river (Figure 7(b)). However, turbidity levels consistently exceeded permissible limits at all locations, highlighting a significant issue with suspended particles that could negatively impact aquatic life and complicate water treatment processes (Figure 7(c)). Hardness levels were found to be within acceptable limits at all locations, indicating no major concerns regarding water hardness (Figure 7(d)). Chloride concentrations were generally within permissible limits, although some variability was observed, with a few samples at each location slightly deviating either below or above the acceptable range (Figure 7(e)). The QUAL2E analysis reveals that while pH, alkalinity, hardness, and chlorides generally meet IS 10500:2012 standards, turbidity is a significant concern across all sampled locations (Figure 8). This highlights the need for targeted interventions to address suspended particulate matter in the Pawana River. Continuous monitoring and specific measures to reduce turbidity will be crucial for maintaining both ecological and public health standards.

4.2 Comparative Analysis of Pawana River with Other Rivers

The water quality assessment of the Pawana River was compared with findings from various studies conducted

Table 7. Comparative analysis of Pawana River with other rivers

River	Region	Key Observations
Pamba River	India	Application of the QUAL2K model highlighted pollution from untreated discharges and urbanization.
Yamuna River	India	Severe pollution due to urban runoff and industrial waste; QUAL2K modelling used for quality prediction.
Sava River	Slovenia	Effective modelling with QUAL2E; challenges included agricultural runoff and industrial pollutants.
Cau River Basin	Vietnam	Integration of SWAT and QUAL2K revealed sedimentation and turbidity issues from unregulated land use.
Zarjoob River	Iran	Variable hydrological regimes impacted turbidity and nutrient patterns; QUAL2E model calibrated.
Thames River	United Kingdom	Advanced wastewater treatment has helped restore water quality; turbidity is reduced via buffer zones.
Tungabhadra River	India	High levels of organic pollution are attributed to agricultural runoff and untreated sewage.

on other rivers globally to contextualize its results and draw meaningful insights into pollution trends and mitigation strategies (Table 7).

The Pawana River faces turbidity challenges like those observed in the Yamuna and Zarjoob Rivers, primarily driven by factors such as urban runoff and construction activities. To address these issues, advanced modelling tools like QUAL2K and QUAL2E, successfully applied to rivers such as the Pamba, Yamuna, and Cau, offer valuable insights into pollution dynamics and provide a robust framework adaptable to the Pawana River's context. Furthermore, lessons from the Thames and Sava rivers highlight the critical role of implementing buffer zones and improving wastewater treatment to effectively mitigate pollution. This comparative analysis emphasizes the global importance of adopting targeted interventions and utilizing advanced modelling tools for sustainable water quality management.

5.0 Conclusion

The water quality of the Pawana River was analyzed using the QUAL2E software, with data collected across four intervals (Day 1, Day 15, Day 30, and Day 45) and compared against IS 10500:2012 norms. This methodology facilitated a detailed evaluation of key parameters—pH, alkalinity, turbidity, hardness, and chlorides—across three locations: Near Mahadev Mandir (Punawale), Near Pumping Station (Ravet), and Below Saint Tukaram Bridge. The analysis revealed that pH values were generally within the permissible range of 6.5 to 8.5, except for one sample at Location 2 on Day 30, which recorded a value of 8.9, indicating potential alkalinity issues. Alkalinity levels ranged from 121 to 253 ppm, well within the acceptable range of 30 to 400 ppm, reflecting a stable buffering capacity that minimizes abrupt pH changes. Hardness values were also consistently within permissible limits (below 200 ppm), indicating no significant issues related to calcium or magnesium deposits. Chloride levels largely complied with the norms (50 to 200 ppm), with occasional slight deviations below the minimum threshold, suggesting localized variations in water composition. However, turbidity emerged as a critical concern, with levels significantly exceeding permissible limits (below 5–15 NTU) across all locations and sampling days. Values reached as high as 198 NTU (Location 2, Day 15), representing exceedances ranging from 1180% to 3960% above the acceptable range. Elevated turbidity is a clear indicator of suspended particles in the water. To effectively address the issue of elevated turbidity in the

Pawana River, it is crucial to conduct a comprehensive investigation into its underlying sources. Key contributors such as urban runoff, construction activities in nearby locations, industrial and commercial effluents, and soil erosion within the catchment area must be systematically analyzed. Identifying specific locations with high turbidity levels and assessing temporal variations will provide critical insights, enabling the formulation of targeted and sustainable mitigation strategies to reduce turbidity and its associated impacts. This not only reduces water clarity but also impacts aquatic ecosystems by obstructing light penetration, disrupting photosynthesis, and impairing the physiological functions of aquatic organisms. From a public health perspective, high turbidity complicates water treatment processes by reducing the efficacy of disinfection methods and potentially allowing harmful pathogens to persist.

The results highlight the need for regular monitoring of water quality, particularly turbidity, to manage and mitigate deviations effectively. Future research should focus on identifying the specific sources of elevated turbidity, such as sedimentation or industrial effluents, to design targeted interventions. Mitigation strategies, including erosion control, improved wastewater management, and stricter regulations on industrial discharges, are essential to address this issue. By implementing these measures, the Pawana River can sustain its ecological health and remain a vital resource for human and environmental needs.

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7.0 Declaration of Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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