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Development of an Index for Assessing Water Quality in the Kelani River Basin



Why River Water Quality Matters?

Water is a vital element for all living beings. Its quality significantly impacts both public health and the ecological systems. Rivers, which are primary source of freshwater, are increasingly facing threats from urbanization, industrialization, agricultural runoff, and climate change. These impacts are amplified in urban river systems, that traverse densely populated urban areas, where high resource demand and increased pollutant discharge intensify the condition of the water degradation [1]. The Kelani River basin, located in close proximity to Colombo, is among the most significant river system in Sri Lanka. It serves as a primary supply of drinking water for a large portion of the country's population, especially within the capital region, while also supporting industrial, agricultural, and domestic needs. Due to its passage through highly urbanized and industrialized areas, the river is increasingly exposed to pollution from municipal waste, industrial discharge, and surface runoff, leading to growing concerns about its water quality.

Traditional water quality assessments rely heavily on continuous monitoring, which can be costly and resource-intensive. Such approaches are often difficult to sustain in developing regions where monitoring infrastructure may be limited. Therefore, the need for an efficient, adaptable, and simple method to assess water quality is essential, particularly in regions where infrastructure for continuous monitoring is lacking.

In response to this need, a water quality index (WQI) has been proposed using fuzzy theory. Fuzzy theory provides a way of representing situations where a value does not belong completely to only one category. For example, rather than treating a water-quality measurement as simply "good" or "poor," fuzzy theory allows a measurement to have characteristics of both categories to different degrees. This is useful because water quality often changes gradually rather than switching suddenly from one condition to another. By representing these gradual changes, the proposed fuzzy based index can provide a more flexible representation of the overall condition of the river. This method offers a more dependable and understandable way to assess river water quality by including diverse physical, chemical, and biological factors [2]. The study focuses on the Kelani River basin in Sri Lanka, using data collected from nine monitoring stations to evaluate water quality through a fuzzy logic framework, offering a comprehensive and sustainable solution for managing river water resources.

How We Assess Water Quality?

The study used fuzzy theory framework to evaluate the water quality within the Kelani River basin. Fuzzy theory was applied to handle the inherent uncertainty and imprecision in the water quality data. Nine monitoring stations were selected to represent different parts of the river basin, providing a diverse range of water quality data. The parameters chosen for analysis include temperature, turbidity, pH, electrical conductivity (EC), nitrate concentration, dissolved oxygen (DO), and biochemical oxygen demand (BOD), each of which represents crucial aspects of river water quality [3]. Each water quality parameter was classified into three levels based on water quality standard as shown in Table 1. These categories are namely Low, Medium, and High. These linguistic levels were represented using triangular, semi-trapezoidal, and trapezoidal membership functions, depending on the characteristics of the data. The proposed WQI can be calculated whenever new monitoring data become available. For routine monitoring, monthly or seasonal calculation would allow changes in water quality to be tracked over time, particularly during periods of varying rainfall and human activity. Annual summaries can also be used to identify longer-term trends. Therefore, the index is not restricted to a single update frequency and can be applied according to the availability and frequency of water quality monitoring data.

Table 1: Water Quality Risk Level Classification.

Parameter	High	Moderate	Low
Temperature (°C)	$T \leq 20$	$20 < T \leq 27$	$T \geq 27$
Turbidity (NTU)	$T \leq 5$	$5 < T \leq 15$	$T \geq 15$
pH	$6.5 \leq pH \leq 7.5$	$6.0 \leq pH < 6.5$ or $7.5 < pH \leq 8.5$	$pH < 6.0$ or $pH > 8.5$
Electrical Conductivity (mS/cm)	$EC \leq 0.5$	$0.5 < EC \leq 1.0$	$EC \geq 1.0$
Nitrate (mg/L)	$NO_3 \leq 10$	$10 < NO_3 \leq 15$	$NO_3 \geq 15$
Dissolved Oxygen (mg/L)	$DO \geq 7$	$5 < DO \leq 7$	$DO \leq 5$
Biochemical Oxygen Demand (mg/L)	$BOD \leq 2$	$2 < BOD \leq 4$	$BOD \geq 4$

The Fuzzy Ordered Weighted Averaging (OWA) operator was used to aggregate the different parameters into a final Water Quality Index (WQI), allowing for a robust and interpretable assessment of water quality. Figure 1 shows the steps involved in the model development process.

What the Kelani River Data Reveal?

In 2022, 2023 and 2024 the water quality level of the selected nine stations was evaluated using the proposed index, and the results are shown in Table 2.

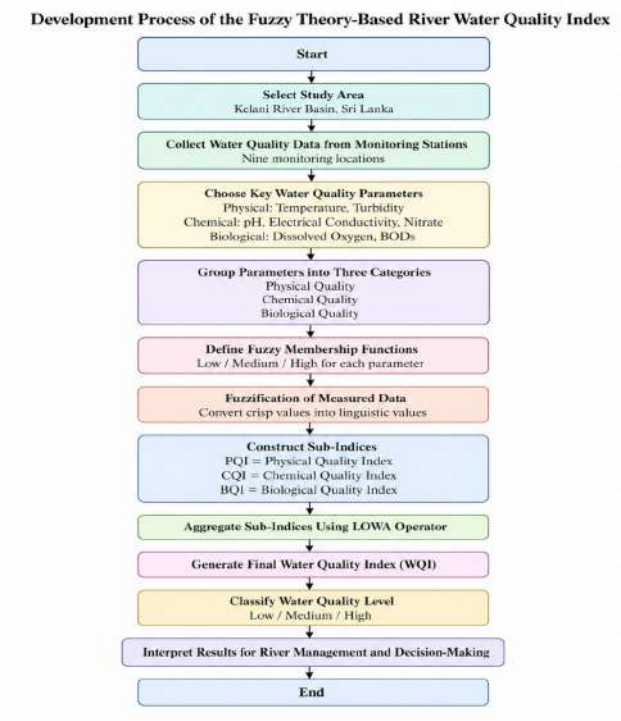


Figure 1: Model Development Steps of the Fuzzy Theory-Based River Water Quality Index.

The water quality assessment conducted from 2022 to 2024 across the Kelani River Basin revealed both stable trends and notable fluctuations among monitoring stations. Weliwita maintained "High" quality across all three years, indicating a stable and less polluted environment. Wak Oya, Kaduwela, and Hanwella also showed "High" levels in both 2023 and 2024, with Wak Oya improving from "High" (2022) to remaining "High" thereafter. Seethawaka experienced "Medium" in 2022, improved to "High" in 2023, but dropped back to "Medium" in 2024. This fluctuation suggests intermittent pollution events or seasonal variations that require closer monitoring. Pugoda Ferry, Pugoda Ela, and Raggahawatta consistently recorded "Medium" levels in 2023 and 2024, with Raggahawatta remaining at "Medium" across all three years. These locations likely face ongoing moderate stress from surrounding land use activities. Pusseli Oya showed a decline from

Table 2: Water Quality Levels in Kalani River Bain.

Station	Water Quality Level		
	2022	2023	2024
Weliwita	High	High	High
WakOya	High	Medium	High
Pugoda ferry	Medium	Medium	High
Pugoda Ela	Medium	Medium	High
Kaduwela	High	Medium	High
Hanwella	High	Medium	High
Seethawaka	Medium	High	Medium
Raggahawatta	Medium	Medium	Medium
Pusseli oya	Medium	Medium	Low

"Medium" in 2022 and 2023 to "Low" in 2024. This change warrants further investigation, as it indicates a deterioration in the observed water-quality condition. The decline may be associated with factors such as agricultural runoff, domestic waste, or industrial discharge; however, the present study did not directly investigate pollution sources. Further source-identification studies are therefore required to determine the factors contributing to this change. Overall, while the majority of the Kelani River Basin maintained good water quality, localized degradation at Seethawaka, Raggahawatta, and especially Pusseli Oya requires immediate attention. Continued monitoring and source identification studies are strongly recommended for these vulnerable stations.

What This Means for the Kelani River

This study introduces a fuzzy theory-based water quality index that includes physical, chemical, and biological parameters to assess river water quality. By applying fuzzy theory, the method accounts for uncer-

tainty in water quality data, offering a more reliable and interpretable approach than traditional indices. The case study of the Kelani River basin showcases the adaptability and strength of the suggested approach, highlighting the importance of a flexible, decision-support tool for river water management. The developed Water Quality Intex (WQI) can be easily adapted to other river basins, providing an essential tool for decision makers and environmental authorities to make well informed decisions regarding water resource management and protection.

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