

Evaluating Water Potability: A Fuzzy Logic Approach

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Abstract.

Water is among the fundamental resources available on Earth, crucial in ensuring life, especially acting as drinking water. On the contrary, the resource distribution of water on Earth varies from one region to the other. Whereas some regions receive ample water supplies, others face water scarcity. This shows unequal potential and, therefore, demands regional analysis. This research determines whether water is potable or not based on the analysis of a dataset found on Kaggle¹; specifically, the sources of water analysed here are from India. In this paper, we will apply the fuzzy AHP method to evaluate and prioritize various factors affecting the water potability. Then, by considering the obtained factors in priority order, we will develop a model for predicting the potability of water resources. As a result, water quality features are independent from each other, and all of them must satisfy the standard conditions so that water is considered potable. The present study offers some clear insight into the aspects of water quality assessment and a more feasible way of prediction concerning water potability based on given certain measurable factors.

Keywords. Fuzzy TOPSIS Water Probability, Fuzzy AHP, Prediction

1. INTRODUCTION

Rapid industrialization and urbanization in India have resulted in severe deterioration of water quality. The untreated sewage, rampant disposal of plastics and other pollutants into rivers, lakes, and ponds, along with industrial waste, has contaminated nearly 70% of the available water resources of the country. This has consequently emerged as an unprecedented water pollution crisis in which as many as 80% of the rural population and 20% of the urban population have no access to potable water. The implications are extremely serious: diarrhea, dysentery, typhoid, cholera, and hepatitis are waterborne diseases in the country. Literally millions of people get afflicted by these diseases every year. These diseases strike children with particular vengeance and, together, give some of the worst mortality rates, creating a vicious circle of poverty and ill health. In the backdrop of such facts, there is an immediate need for effective water quality monitoring to help overcome some of the challenges facing local communities. This paper presents the way fuzzy logic can help in solving the issues related to traditional methods for water quality assessment, especially when resources are limited. The awareness that this research possesses of the critical issue at hand-water potability-allows it to play its part in the worldwide attempt to ensure safe, accessible drinking water.

2. RELATED WORK

Over the years, various methods have been developed to assess water quality, with traditional approaches often relying on statistical techniques to calculate water quality indices (WQIs) [1]. Fuzzy logic was first introduced by Lotfi Zadeh in the 1960s as a mathematical framework for dealing with imprecision and reasoning that mimic human decision-making processes. [2] Unlike traditional binary logic, which categorizes data into discrete classes, fuzzy logic allows for degrees of membership in different sets, making it particularly suitable for environmental applications where data often contains ambiguities and uncertainties. Fuzzy logic offers a more flexible and precise approach to water quality assessment. [3] By incorporating fuzzy reasoning, a fuzzy logic-based WQI can map input determinants, such as physicochemical parameters, to output results that better reflect the continuous nature of water quality data. In the fuzzification stage, real-world data is transformed into fuzzy sets using membership functions, which represent the degree to which each data point belongs to a specific set. [4] For example, instead of classifying water as simply "good" or "bad," fuzzy logic allows for a range of values that can more accurately describe the water's quality. [5] Fuzzy set operations are then used to derive fuzzy results, which are subsequently converted into real values through the process of defuzzification. [6] This is particularly important in water quality management, where factors such as pollution levels, seasonal changes, and human activities can cause significant fluctuations in water quality. [7] This flexibility makes fuzzy logic an ideal tool for assessing water quality in diverse environments, from urban areas with complex pollution sources to rural regions where data may be sparse or incomplete. Additionally, fuzzy logic can incorporate additional critical parameters that may not be included in traditional WQIs, such as heavy metal content or emerging contaminants, further enhancing the accuracy of the assessment [8]. Bellur et al. [9] assessed water quality using ML techniques.

3. METHODOLOGY

There are many methods to choose the best parameters to minimize the water loss. But we are going to consider only some methods for the evaluation.

3.1. *AHP*

The Analytical Hierarchy Process (AHP) is a multi-criteria decision-making technique that aids in prioritizing and evaluating complex options by organizing them into a hierarchical structure. This method is commonly used by professionals to facilitate strategic planning and guide decisions effectively.

3.2. *FAHP*

Fuzzy AHP extends the traditional AHP by incorporating fuzzy logic to better handle uncertainties and ambiguities in decision-making. Fuzzy AHP is particularly useful when human judgments are imprecise or uncertain, and it offers a systematic way to address these complexities.

4. RESULTS

4.1. *AHP*

In this analysis, we evaluated the potability of water samples based on several criteria. The consistency of our judgment matrix was confirmed with a Consistency Index value of 0.05, which aligns well with the random consistency index of 0.0556. This indicates that our judgments regarding the criteria are consistent and reliable. These ranking highlights that the most significant factors in determining water potability are pH and Hardness, followed by Solids, Conductivity, and Organic Carbon. The criteria Chloramines, Sulphate, Trihalomethanes, and Turbidity have less impact on the final assessment. The AHP analysis identified pH as the most important water quality parameter (0.405), followed by Hardness (0.247) and Solids (0.221).

4.2. *Fuzzy AHP*

In the final step the normalized values of all attributes are obtained which is seen in Table I. The fuzzy AHP analysis provides a robust framework for assessing water potability by accommodating the uncertainty and vagueness inherent in evaluating multiple criteria. The findings highlight the importance of Trihalomethanes and Conductivity in determining water quality, suggesting that these factors should be prioritized in water quality assessments and treatment processes. By applying fuzzy AHP, we can more effectively prioritize and manage the criteria affecting water potability, leading to better-informed decisions and improved water safety. This method helps in making nuanced assessments that account for the complexities and uncertainties involved in evaluating water quality.

TABLE I: Normalized Data

Sl.no	Normalized values	Condition
1	0.1463	ph
2	0.126	Hardness
3	0.5937	Solids
4	0.2766	Conductivity
5	0.5342	Organic carbon
6	0.6468	Chloramines
7	0.2622	Sulphate
8	0.7242	Trihalomethane
9	0.0023	Turbidity

5. CONCLUSION

In conclusion, the integration of fuzzy logic with AHP offers a robust framework for water quality assessment, accommodating the inherent uncertainties and complexities of evaluating multiple criteria. This approach enables more informed decision-making and enhances water safety management. By prioritizing critical factors such as Trihalomethanes and Conductivity, policymakers and water resource managers can better address water quality issues and implement effective preventive measures. The advancements presented in this study have the potential to revolutionize water quality monitoring practices, contributing significantly to public health and sustainable water management globally.

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