ASSESSMENT OF WATER QUALITY INDEX USING FUZZY LOGIC

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ABSTRACT

The aim of this study is to develop a framework to determine water quality index using fuzzy inference system. Water quality index (WQI) is basically a deterministic parameter based upon the concentration of several pollutants such as nitrate, pH, fluoride, total dissolved substance (TDS), total hardness (TH), biochemical oxygen demand (BOD), sulphate, manganese, Iron, temperature, etc. measured at the laboratory with a standard equipment under the guidelines of specific protocol. Samples collected from a study area of various districts of Karnataka. Several researches have been already carried out to estimate the water quality index using traditional statistical methods. However, water quality dataset at any specific location of our study area being a time series has got the missing information because the detection limit of the measurement techniques used. The presence of this missing information provides the knowledge of the concentration of pollutant is in the range, inviting the researcher to apply fuzzy set theory to estimate the WQI. With a motivation towards data science and application of fuzzy logic, here we have developed an inference engine to estimate the WQI. Our inference engine is based on Takagi-Sugeno implication. In order to reduce the rule structure, we have used hierarchical system. Results are well in agreement with the results that by traditional statistical technique.

Keywords: *Water quality index, Takagi-Sugeno model,*
Concentration, detection limit

INTRODUCTION

Presently the protection of environmental and water quality management has become a significant issue in public policies all over the world. Availability of fresh and clean water for human utilization is one of the most important issues. Classification of water resources to satisfy water quality standards is an important issue in this respect. Human body is a water mechanism designed to run primarily on water and minerals. The movement of water within the cellular system also transports very important blood plasma, 92% of which is made up of water. It confirms the quality of water which is consumed will have severe impact on the overall condition of health. Human brain contains more than 80% water and controls each and every progression that happens within our body. Considering the very important role that water plays in our brain and nervous system is key to long life. The purity of water we drink causes impact on human strength and energy level. The quality of drinking-water is a powerful environmental determinant of health. Assurance of drinking water safely is a foundation for the prevention and control of water borne disease. The biggest problem with water today is that the public does not really believe there is anything wrong with it. People think water problem begin when the water starts to develop bad smell, taste or look dirty, however, harmful pollutants and contaminants usually don't make water smell or taste bad. Today an estimated 50 to 70% of the populations, in rural areas are drawing water form "Poisoned lakes, streams and water tap ". Chemicals and Viruses are actually passed into households for everyday use and can cause cancer, Birth defects and genetic damage .According to the World Health Organization- "80% of all diseases are water borne". One can go without food for almost two months, but without water only a few days. So if people don't drink sufficient pure and clean water, they can damage every aspect of their physiology.

INTRODUCTION TO FUZZY LOGIC

The term fuzzy refers to things which are not clear or are vague. In the real world many times we encounter a situation when we can't determine whether the state is true or false, their fuzzy logic provides a very valuable flexibility for reasoning. In this way, we can consider the inaccuracies and uncertainties of any situation.

In Boolean system truth value, 1.0 represents absolute truth value and 0.0 represents absolute false value. But in the fuzzy system, there is no logic for absolute truth and absolute false value. But in fuzzy logic, there is intermediate value too present which is partially true and partially false.

Fuzzy logic was introduced by Zadeh (1965).Great attention has been paid to the development of environmental indices based on fuzzy logic .The Fuzzy water quality index developed by Ocampo-Duque et al (2006) included 27 parameters. Fuzzy logic is a new approach to computing based on degrees of truth, differing from the true or false Boolean logic of the modern computer. Fuzzy logic includes 0 and 1 as extreme cases of truth but also includes the various states of truth in between Fuzzy logic appears similar to the reasoning of human mind. The fuzzy system is capable of working with complex systems under uncertain and imprecise conditions Fuzzy logic is usually used for building fuzzy rules that can be easily understood by humans. Therefore, it is common to describe fuzzy variables as linguistic variables. The linguistics variables that we will use in this research are mild, moderate, severe and very severe for both the input and output parameters in the fuzzy model. By using those linguistic variable, fuzzy ifthen rules which are the main output of the fuzzy system would be set up: generally presented in the form of: if x is A then y is B where x and y are linguistic variables and A and B are linguistic values, determined by their fuzzy sets. The first part of the rule is called the antecedent, and can consist of multiple parts with the operators AND or OR between them. The latter part is called the consequent, and can also include several outputs.

Fuzzy logic is determined as a set of mathematical principles for knowledge representation based on degrees of membership rather than on crisp membership of classical binary logic. This powerful tool to tackle imprecision and uncertainty was initially introduced by to improved tractability, robustness and low-cost solutions for real world problems. Fuzzy sets have been applied in many fields in which uncertainty plays a key role [1]

BLOCK DIAGRAM OF FUZZY INFERENCE SYSTEM

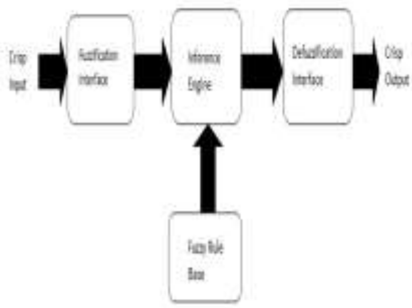


Fig : Block Diagram of FIS

Fuzzy Inference System Architecture:

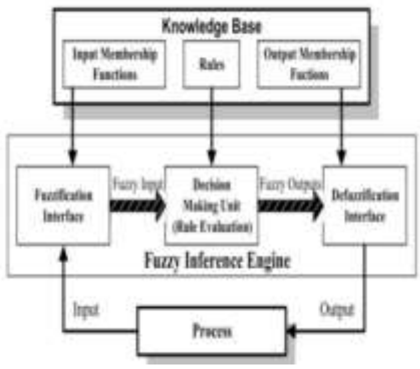


Fig 3.3.1: FIS Architecture

DEFUZZIFICATION:

This is the process of calculating a scalar value from the fuzzy output. From composition we obtain a single fuzzy set. Defuzzification aggregates the set into a single value. The common techniques used are the centroid and maximum methods. In the centroid method, the scalar value of the output variable is computed by finding the variable value of the center of gravity of the membership function for the fuzzy value.

The general formula is

$$\bar{X}_{centroid} = \frac{\int_a^b \mu(x)\, x\, dx}{\int_a^b \mu(x)\, dx}$$

Where [a, b] is the interval of the aggregated membership function. In the maximum method, the value at which the fuzzy subset has its maximum truth value is chosen as the value for the output variable.

IMPLEMENTATION

Selection of input Parameters:
We have collected the data of ground water from various districts of Karnataka namely Bijapur, Chikhallapur, Bangalore rural, Chamarajanagar and many others.

Selection of output Parameters:
The output parameter selected is water quality index(WQI)

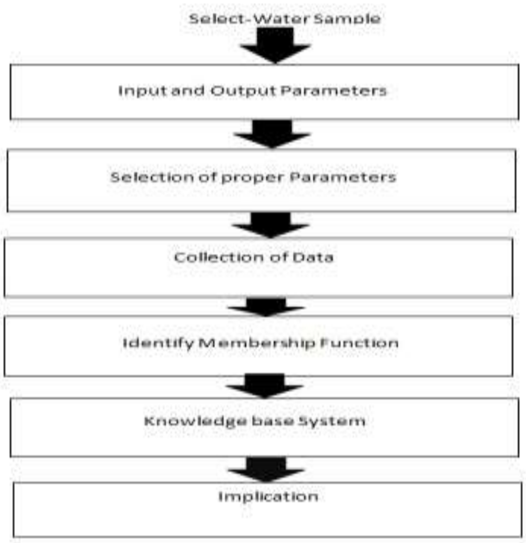
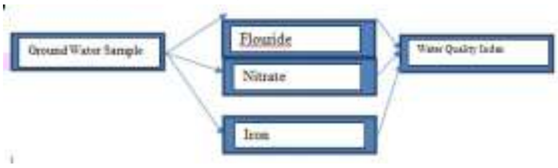


Fig : Flow Chart of Water Sample Analysis

Selection of proper parameters:
The different elements that are under our consideration are

Iron, Fluoride, and Nitrate



Collection of Data: We have studied the different datasheets of ground water over the years of each of these district and calculated the WQI of each of the collected sample based on different parameters i.e. the different elements present in it.

Identify Membership functions:
Membership function for input is split into 3 rangesLow, Moderate, High Membership function for output is divided into 4 rangesVery Poor, poor, Good, Very Good

Knowledge based system:
IF-THEN rules are used

Implication:
The percentage of the amount of each of the above mentioned elements present in the collected ground water samples were compared with the standard WHO values and based on that the quality of ground water suitable for drinking was evaluated The practical implementation for the determination of WQI is done using Fuzzy Inference System (FIS)

Steps to calculate WQI:

a. Collect the amount of different components present in water

b.Split the range into 3 sections namely Low, moderate and high.Perform the same for each of the elements (3 elements)

c. Choose a common range for the output that is going to determine water quality for each of the district.

d.Split the range into 4 sections namely Very Poor, Poor, Good, and Very Good.

e. IF-THEN rules are set for each parameter
f. Rules are viewed in graphical manner
g.We can understand the effect of each parameter on Fuzzy Index based on maximum and minimum values taken for each parameter on their respective ranges.

2.Membership functions of Three Different Parameters

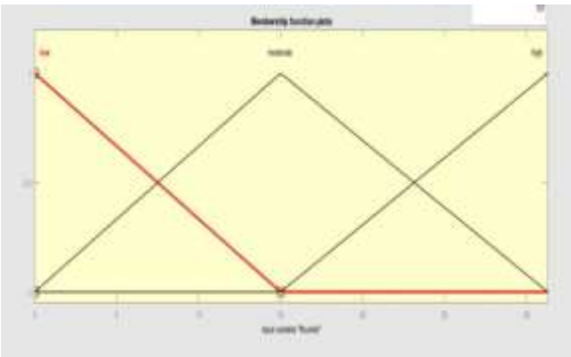


Fig.1- Floride

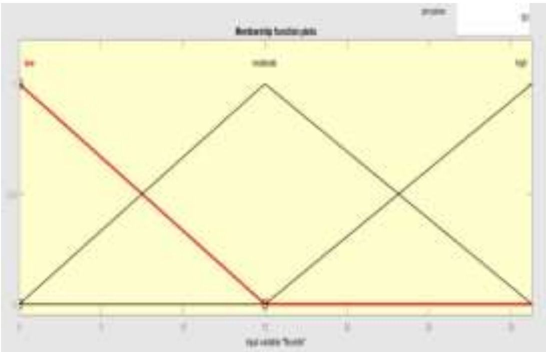


Fig 2 : Nitrate

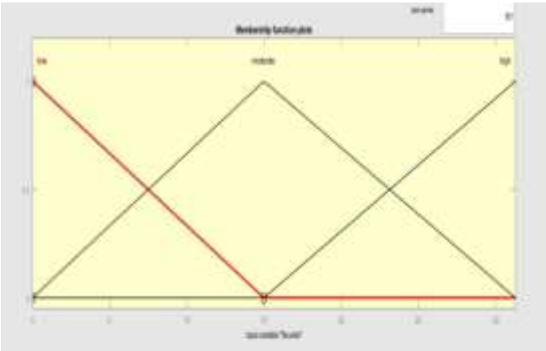


Fig 3 : Iron

MEMBERSHIP FUNCTION OF WATER QUALITY INDEX (WQI):

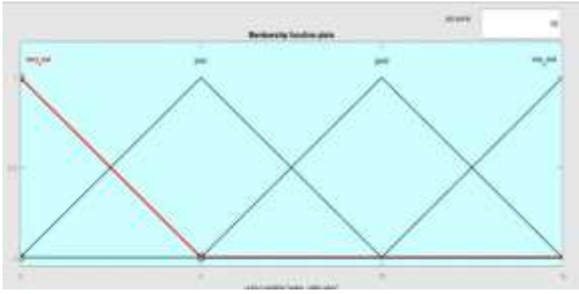


Fig 4: Water Quality Index(WQI)

ADD RULES:

Fig 5: IF-THEN Rules

EN Rules: IF all parameters are set Low THEN WQI is Very Poor

IF all parameters are set High THEN WQI is Very Good

IF all parameters are set Moderate THEN WQI is Good

IF one of the parameters is set poor and other are set Moderate THEN WQI is good

IF one of the parameters is set Moderate and other are set poor THEN WQI is Very poor

IF one of the parameters is set High and other are set poor THEN WQI is poor

IF one of the parameters is set High and other are set Moderate THEN WQI is good

IF one of the parameters is set poor and other are set High THEN WQI is good

IF one of the parameters is set Moderate and other are set High THEN WQI is very good

Elements	W.H.O standard for water quality index(mg/L)
1. Iron	10-50
2. Fluoride	1-1.5
3. Sulphates	250
4. Nitrates	<45
5. TDS	<=300
6. Manganese	<0.05
7. PH	6.5-8.5

The above table defines the limits for standards of different elements suitable for drinking

5.4 DETERMINATION OF WQI:

If WQI lies

1. <=5 then the quality of water are Very Poor and is not suitable for drinking purpose

2. 5-10 then the quality of water is Poor and is still not suitable for drinking purpose

3. 10-15 the quality of water is good and is suitable for drinking only after treatment

4. 15 and above the quality of water is Very Good and is suitable for drinking purpose.

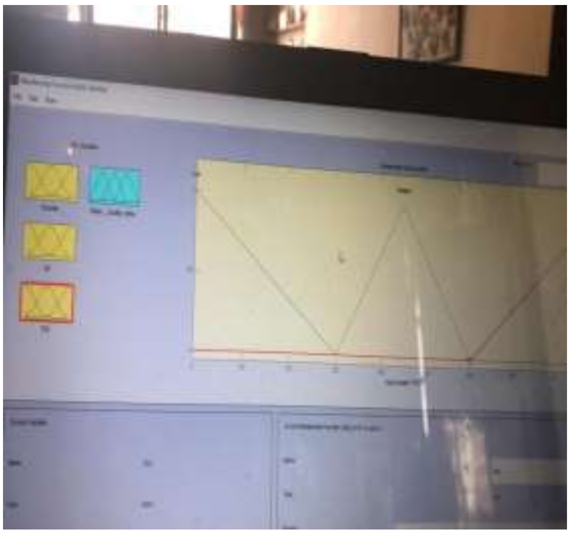
In the above output, the WQI lies in the range of 0-5 (i.e. 4.5), so we can conclude that the quality of water for Bijapur district is Very Poor and should not be consumed

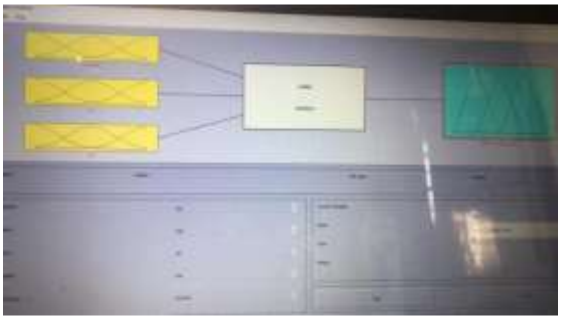
This is a very serious problem and immediate action should be taken.

Similar steps should be taken for the following districts.

RESULTS

The WQI was used to aggregate diverse parameters and their dimensions into a single score,. It was observed from the computed annual WQI that the values ranged from 53.18 during 2000 to 101.26 during 2009 and therefore can be categorized into "Good water" during 1978, 1979, 1980, 1999, 2000, 2008 to "Poor water" during 2009. However, it was generally observed that 14%, 80.50%, and 5.50% of all monthly computed WQI values from 1978 to 2009 have fallen under "Excellent", "Good", "Poor", water quality respectively. In addition, the use of fuzzy logic seems the clearest innovation in the last decade and it is appropriate for an accurate WQI. This approach allows to evaluate the impact of each variable in the final index of the quality of the water. However, it remains to establish weighting factors for specific water use. These weighting factors must be locally determined. There is a need of regular and detailed water quality monitoring of the Rivers which is presently carried out by the state pollution control board. There is a need to the identify changes or trends in water quality over time and space, to obtain necessary information to design specific pollution prevention programs and to determine whether goals such as compliance with pollution regulations or implementation of effective pollution control actions are being met.





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