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Fuzzy expert system for drinking water quality index

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Abstract
The role of water in human life is significant as it plays a very essential role in the procedure of human body. Fuzzy logic provides an efficient and useful device for classifying drinking water quality based on limited observations. In this study, a Fuzzy Drinking Water Quality Index (FDWQI) is proposed for evaluation of water quality for drinking purpose. Fuzzy expert system makes it possible to combine the certainty levels for the acceptability of water based on an approved parameter.

Keywords: Water Quality Index, Fuzzy Logic, Fuzzy Expert System, Water Quality Classification. Drinking water Quality Index.

INTRODUCTION

Now a day's environmental protection 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. Because Human body is a water mechanism designed to run primarily on water and minerals. The movement of water within our cellular system also transports very important blood plasma, 92% of which is made up of water. It confirms the quality of water we drink will have severe impact on our overall condition of health. Our 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 our 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 waterborne 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 our 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". We 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.

Water quality of any specific area or specific source can be assessed using physical, chemical and biological parameters. The values of these parameters are unsafe for human health if they occurred more than defined limits [1, 2, 3, and 4]. Therefore, the suitability of water sources for human utilization has been described in terms of Water quality index (WQI), which is one of the most efficient and useful ways to explain the quality of water. It has been realized that the use of human being water quality parameter in order to explain the water quality for general public is not logical and simply understandable [5,6]. So for that WQI has the ability express the data in a simplified and logical form it takes information from a number of sources and combines them to develop an overall status of a water system. They increase the understanding ability of highlighted water quality issues by the policy makers as well as for the general public as users of the water resources. The present study developed a fuzzy expert system for water quality index, which is easy to understand, logical and useful for common people.

Initially, WQI (water quality index) was developed by Horton (1965) [7] in United States by selecting 10 most commonly used water quality parameter. Like dissolved oxygen (DO), pH, coli forms, *turbidity* specific conductance, alkalinity and chloride etc. and has been usually applied and accepted in European, African and Asian countries. Furthermore, a new WQI similar to Horton's index has also been developed by the group of Brown in 1970 [8], which were based on weights to individual parameter. Recently, many modifications have been considered for WQI concept through various scientists and experts [9, 10].

A fuzzy logic approach to analyzing water quality could help reduce the number of people in the developing world forced to drink polluted and diseased water for survival. In this paper, we explain a new approach to water quality evaluation uses fuzzy logic to combine different problems and provide a more precise indicator of overall quality [6].

Fuzzy logic provides a structure to model ambiguity. Fuzzy logic was first introduced by Zadeh (1965) [11]. Kumar et al. [12] has used the concept of degree of match in fuzzy environment to study the water pollution of Sangam Zone, Allahabad in 2004 and

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assessment of quality of water rivers Ganga and Yamuna during Ardh Kumbh 2007 was studied by Yadav [13] under the supervision of Pankaj Srivastava. Raman et al. (2009) believed that fuzzy logic concepts, if used logically, could be a capable tool for some of the environmental strategy matters [14]. Jinturkar et al. (2010) used the fuzzy logic for evaluating the water quality index on the basis of which, water quality rankings are given to determine the quality of water. The fuzzy index has been shown to be efficient in avoiding the loss or non-detection of information critical for classification of water quality (Roveda et al., 2010) [15]. Babaei Semiromi, F,,Hassani, A.H.,Torabian A., Karbassi, A.R and Hosseinzadeh Lotfi was developed a water quality index for karnoor river of Iran during 2011 [16]. A water quality index was developed by Pankaj Sriivastava, Anjali Burande and Neeraja Sharmal at sangam jone during mahakubh 2013 [17].

In this study, the fuzzy logic has been used to assessment of drinking water quality by developing a Fuzzy Expert System for drinking water quality index based on fuzzy logic.

MATERIALS AND METHOD

Fuzzy expert System

Fuzzy Expert System (figure no.1) is a rule based expert system where fuzzy logic is used as a tool for representing different form of knowledge about the problem.

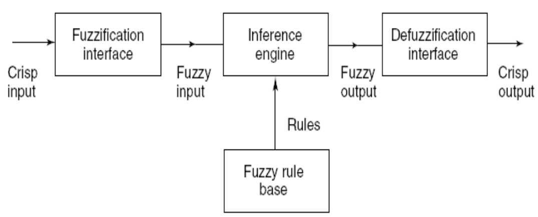

Fig 1. Fuzzy Expert System

The proposed system consists of 5 input, 1 output and 10 rules and actual flow diagram for fuzzy expert system is shown in Fig. 2. The present system is used for developing a drinking water quality index.

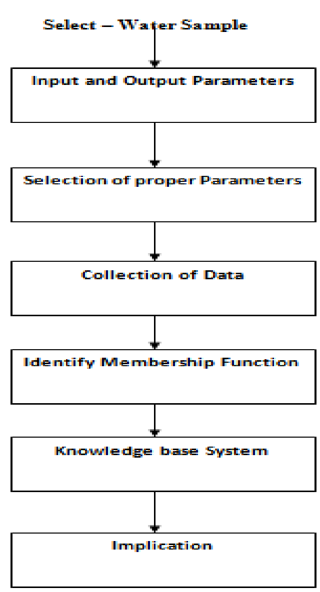

Fig 2. Flow diagram of fuzzy Expert system

Here FWQI based on five input parameter. System output is actually giving the drinking water quality which is divided into four types. The knowledge base describing the system's behavior is represented by the membership functions designing the linguistic variables. Hence, for the proposed system's behavior, six linguistic variables are defined. Out of these six, five is input variables namely- turbidity (T), dissolved oxygen (DO), biochemical oxygen demand (BOC), pH value (pH), and Fecal Coli form (FC) and one is output variable drinking water quality. fuzzyfier unit computes the membership values of each input variable in accordance with the fuzzy values defined in the database. Inference engine interprets the rules combined in the rule base. The Inference engine is performed in three steps, (1) antecedent establishment (2) implication (3) aggregation. Finally, defuzzification convert the fuzzy output into cripes value.

Membership Function of Input and Output:

Water quality is determined by its physical, chemical, and bacteriological characteristics and in order to evaluate quality of water. The parameters measured for analysis are turbidity (T), dissolved oxygen (DO), biochemical oxygen demand (BOC), pH value (pH), and Fecal Coli form (FC) Figures 3, 4, 5, 6 and 7. Figure no. 8 shows the membership value of output result. In order to design a user friendly environment model for evaluating drinking water quality.

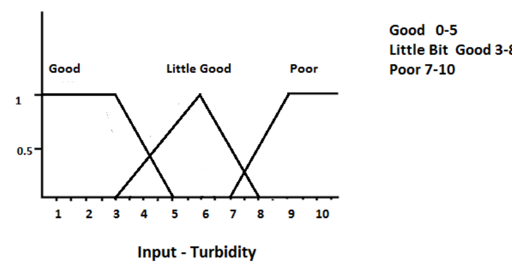

Fig 3. Membership function for Turbidity

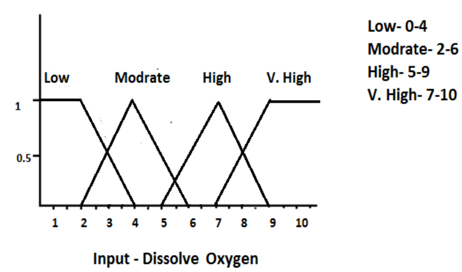

Fig 4. Membership function for dissolved oxygen.

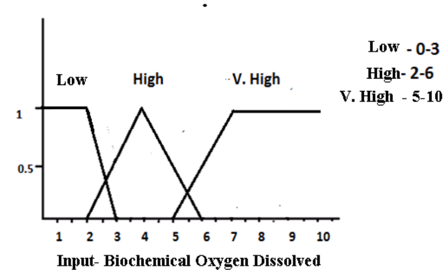

Fig 5. Membership function for Biochemical oxygen dissolved

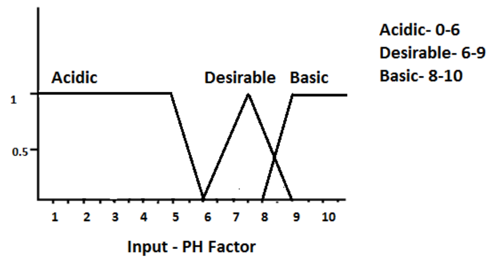

Fig 6. Membership function for pH factor

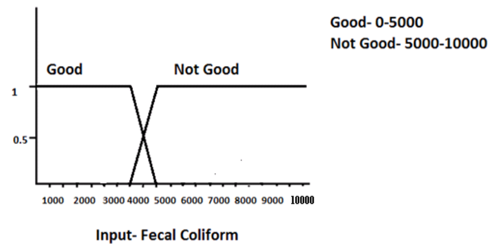

Fig 7. Membership function for Fecal Coli form

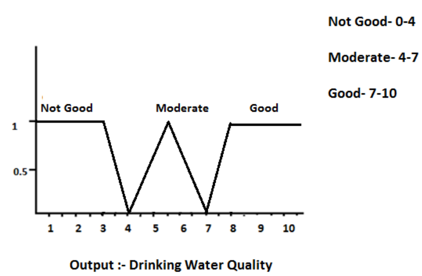

Fig 8. Membership function for Output Result

Input Parameters

Turbidity (T)- Turbidity is categorized into three fuzzy sets with membership functions as follows:

(1) Good (G): 0–5NTU,
(2) Little bit good (LG): 3–8NTU,
(3) Poor (P): 7–10NTU.

Dissolved Oxygen (DO) - DO is categorized into four fuzzy sets and their membership functions are given below:

(1) Low (L): 0–4 mg/L,
(2) Moderate (M): 2–6 mg/L,
(3) High (H): 5–9 mg/L,
(4) Very high (VH): 7–10mg/L.

Biochemical Oxygen Dissolved (BOD) - BOD is categorized into four fuzzy sets and their membership functions are given below:

(1)Low (L): 0–3 mg/L,
(2) High (H): 2–6 mg/L,
(3) V. High (VH): 5–10 mg/L,

PH Factor (pH)- The pH factor is categorized into three fuzzy sets and their membership functions are given below:

(1) Acidic (A): 0-6
(2) Desirable (D): 6 – 9
(3) Basic (B): 8-10

Fecal Coli form (FC) - FC is categorized into four fuzzy sets and their membership functions are given below:

(1) Good (G) : <5000,
(2) Not Good (NG) : >5000.

Output variable is quality of drinking water. There are three classes of drinking water quality and the range for membership function is from 0 to 10.

(1)Good for drinking water: 7 -10
(2) Good for drinking water after treatment: 5-7
(3) Not good for drinking water: 0-5

In this study we use triangle and trapezoidal membership function that defines how each point in the input space is mapped to a membership value between 0 and 1. In order to suggest a user friendly environment model for evaluating Drinking Water Quality Index. Steps of this expert system are - fuzzification, assessment of inference rules, and defuzzification of fuzzy output results. Conception of inference rule is an if–then rule has the form: “If x is A then z is C”, the if–part is called the antecedent, while the then–part is called the consequent. The antecedent and the consequent of a rule can have multiple parts. Fuzzification is process to define inputs and outputs as well as their individual membership function that convert the numerical value of a variable into a membership grade to a fuzzy set. After the inputs are fuzzified, the degree to which each part of the antecedent is satisfied for each rule. If the antecedent of a given rule has more than one part, the fuzzy operator is applied to obtain one number that represents the result of the antecedent for that rule. This number is then applied to the output function. The input to the fuzzy operator is two or more membership values from fuzzified input variables. The output is a only truth value. The input for the inference process is a single number given by the antecedent, and the output is a fuzzy set. Implication is implemented for each rule. Because decisions are based on the testing of all of the rules in an FES, the rules must be combined in some way in order to make a decision. Aggregation is the procedure by which the fuzzy sets that correspond to the outputs of each rule are combined into a particular fuzzy set. Finally, the input for the defuzzification procedure is a fuzzy set (the aggregate output fuzzy set) and the output is a single number. In this research, each of the six input parameter has been divided into different categories and defined by triangular and trapezoidal membership function. The membership functions were assigned as shown in Figure 3,4,5,6, 7 and 8. Water quality index is shown in Table 1and testing of that water quality index (WQI) is shown in table no.2.Five fuzzy sets have been considered to be suitable for this study. Ranges for fuzzy sets were based on CPCB-Indian standard specifications for drinking water is-10500.

Five quality parameters have been selected to estimate water quality by means of an aggregated index called fuzzy drinking water quality index (FDWQI). For the selected set of five parameters, the most prominent 10 rules have been used. For example, fuzzy rule is chosen. Rule 1: If TDS is good, and DO is high .BOD is low, PH is desirable and fecal coli form is good then WQI is good. Same way, other rules can be enunciated. Strength of the system depends on the number and quality of the rules. Every rule in fuzzy rule base system consists of rule antecedents (inputs) and rules consequents (output). Table 1 shows the rule antecedents and consequents for this system.

Table 1. Rule Antecedent and Consequence

S.No.	TURBIDITY	DO	BOD	Ph	FECAL COLIFORM	RESULT
1	Little Good	Low	S. High	Acidic	Good	Good for drinking water after treatment
2	Good	Moderate	Low	Desirable	Good	Good for drinking water
3	Poor	High	Low	Desirable	Not Good	Good for drinking water
4	Poor	Moderate	Low	Desirable	Good	Good for drinking water
5	Little Good	Low	High	Acidic	Good	Not Good for drinking water
6	Little Good	Moderate	High	Basic	Not Good	Good for drinking after treatment
7	Good	Low	High	Basic	Not Good	Good for drinking after treatment
8	Good	Moderate	High	Acidic	Good	Good for drinking after treatment
9	Poor	Low	High	Acidic	Good	Not Good for drinking water
10	Good	Very High	Low	Desirable	Not Good	Good for drinking water

Table 2. Testing of FDWQI

S.No.	TURBIDITY	DO	BOD	Ph	FECAL COLIFORM	RESULT
1	5	2	5	5	4	5
2	5	5	2	8	5	9
3	8	7	2	7	4	9
4	9	4	5	7	3	7
5	6	3	6	4	2	4
6	7	5	4	9	7	6
7	3	2	7	10	5	6
8	9	3	5	4	3	3
9	4	9	2	6	6	8
10	2	8	3	8	6	7

CONCLUSION

Fuzzy logic is the flexible device to develop categorization model with an easy to understand framework and constructed with simple and efficient language. In this study, we developed a fuzzy drinking water quality index, which was obtained to express the categorization of drinking water quality assessment more understandable, especially in public consideration. It is an easy to use and effective fuzzy expert system from which ordinary people can access the quality of their drinking water.

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