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ANALYSIS OF FUZZY LOGIC BASED CONTROL MODEL FOR WATER TREATMENT PLANT IN INDIAN SCENARIO

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ABSTRACT

This paper mainly deals with the design of a Fuzzy Logic Control model for water treatment in Indian scenario. The water treatment plant may differ at different places, depending on the available water and our water requirements. The numerous factors affects the quality of water as well as operation of water treatment plant .The measure of water quality in terms of the presence of different kinds of impurities in water might vary from place to place and time to time. The aim of this study is to analyze the affecting parameter of water quality that affects the water treatment process. Based on the numerical calculations and graphical representations one can identify the corrective measures for an effective water treatment process.

Keyword: water treatment plant, fuzzy logic control, fuzzification, knowledge base rule, defuzzification.

1. INTRODUCTION

Water is an important role in our daily life. It is basic need for all living organism. Also it is precious commodity. Most of the earth's water is sea water. Only 2.5% of the water is fresh water that does not contain major levels of dissolved mineral deposits or salt and two third of that is frozen in ice caps and glaciers. In the total water capacity of the planet only 0.01% of the water is accessible for consumption. Clean drinking water is a basic human need. Unfortunately, more than one in six people still lack reliable access to this precious resource in developing world [22]. With the present population growth-rate (1.9 per cent per year), the populations are expected to cross the 1.5 billion mark by 2050. The Planning Commission, Indian Government has estimated the water demand increase from 710 Billion Cubic Meters in 2010 to almost 1180 BCM in 2050 with domestic and industrial water consumption expected to increase almost 2.5 times. Increasing population, non availability of fresh water resources, urbanization make fresh water scarcity an emerging global issue [WHO guidelines for Drinking Water Quality]. Water in adequate capacity and safe quality is essential for human survival. The quality of drinking water is a health concern as water is a medium for disease transmission. Due to many reasons like increased population, industries, man - made activities water has polluted heavily. Polluted water has harmful contaminants. It is necessary and very important to test the quality water before it is used for consumption.

2. LITERATURE SURVEY

The Aleksandar Rikalovic, ILija Cosi *et al.*, analysed The Fuzzy expert system for industrial Location factor analysis. Abdelnaser omran (2011) was studied about The Factors Influencing water treatment management performance in Malaysia, A case study in Pulau Pinang. VasicKaninova *et al.*, (2015) was described The Fuzzy model - based Neural Network Predictive Control of a Heat Exchanger. Chrysi Laspidou *et al*, (2015) were developed Exploring patterns in water consumption by clustering. Lakhya jyoti phukon *et al.*, (2015) has described Design of fuzzy logic controller for performance optimisation of induction motor using indirect vector control method. Neeru Gupta *et al,* (2012) have analyzed "Application of Neural Networks and Fuzzy Logic for Integer water Management. Sirigiri, p. *et al.*, (2012) was analyzed Evaluation of teacher's Performance using Fuzzy logic Techniques. And R.Giordano, *et al.,* (2007) has analyzed The Integrating conflict analysis and consensus reaching in a decision support system for water resource management. Rehan Sadiq *et al.*, (2006) was evaluated the interpreting fuzzy cognitive maps using fuzzy measures to evaluate water quality failures in distribution networks. Vasic Kaninova *et al.*, (2015) was described The Fuzzy model - based Neural Network Predictive Control of a Heat Exchanger.

3. WATER TREATMENT OVERVIEW

Clean secure water is fundamental for everyday life. Water is essential for strength, hygiene and to develop our community. The need for drinking water treatment has become an increasing necessity in modern civilization. The water treatment process may vary slightly depending on impurities present in the water but basic principles are largely the same. The Water treatment needs chemical process, physical process and sometimes biological process to remove water contaminants. The most common processes used in drinking water treatment are the chemical and physical process. Worldwide popularly used water treatment technology is combination of coagulation, sedimentation and filtration. Also it is the process of removing unwanted chemicals, imminent solids and gases from polluted water. The intention is to produce water fit for a specific purpose. Most water has disinfected for human consumption that is for drinking, but water treatment may also be designed for variety of other purposes, including fulfilling the requirements of medical, pharmacological, chemical and industrial applications. Treatment for drinking water manufacture involves the removal of contaminants from available raw water to

produce quality water for human consumption. Substances has removed during the process of drinking water treatment consist of suspended solids, bacteria, algae, viruses, fungi, and mineral deposits such as iron and manganese.

4. WATER QUALITY PARAMETERS

In this paper we are going to analyze the quality of water affected by the parameter. The quality of water is not equal and constant. Water quality is affected by different type of parameters such as Colour, Turbidity, Total dissolved solids, Taste and odour, PH, Chloride, calcium, magnesium, sulphate, total hardness are the physical and chemical parameters.

4.1 Colour

Colour is measured in Hazen units. Colour can create from organic matter in the soil through or over, which the water has passed. It is optimal parameter consisting in absorbing of a part of spectrum of visible radiation by substances in dissolved in water, colloidal substances, and suspended particles present in water.

4.2 Turbidity

Turbidity is dirtiness of water and is measured by a light scattering technique. Turbidity is a measure of how particles suspended in water affect water clarity.

4.3 pH

pH is a measure of the hydrogen ion concentration of water. The value of Ph is equal to 7 is neutral and greater than 7 is alkaline and less than 7 is an acidic .It is very important because it affects the disinfection process [WHO guidelines for Drinking Water Quality].

4.4 Total dissolved solids

Total dissolved solids means the quantity of particles that are present in water. Seasonal variations exposed that total dissolved solids values were maximum during summer and minimum during winter. TDS in water originate from natural sources like soil and mountain stones, sewage, urban and agricultural runoff and industrial waste water [Qureshimatva UM *et al*., 2015]

4.5 Chloride

Chloride ions are anions and it's measured by titrating method. It present in all natural water .It does not cause a health risk to humans [Dunia Bouaoun *et al*., 2016]

4.6 Calcium

Calcium ions are cation and it's measured by complex metric titration. It is most important for the human body also essential for health and normal growth. Every day necessity is 1-2 grams. Evidence proves that the heart disease is reduced in areas served by public water supply with a high degree of hardness, the primary component of which is calcium. So the presence of the calcium in water is beneficial to our human health [Qureshimatva UM *et al*., 2015]

4.7 Magnesium

Magnesium is also cations and measured by complex metric titration. It is the next major component of hardness. Concentration of magnesium is very significant when considered in combination with that of sulphate [Qureshimatva UM *et al.*, 2015]

4.8 Sulphate

Sulphate is present in all water, Concentration in the water varying according to the nature of environment through which they run.

4.9 Total hardness

Total Hardness is the sum of temporary hardness and permanent hardness. Presence of bicarbonates of Ca++ and Mg++ appears to result temporary hardness, while permanent hardness is caused due to sulphate and chloride. The increased hardness is found during winter and spring while relative poor hardness during summer [Qureshimatva UM *et al.*, 2015].

5. FUZZY LOGIC CONTROL SYSTEM

Fuzzy control is a mathematical system based on fuzzy logic. It analysis the input values in terms of logical variables which takes values between zero to one. It was used in various fields. The fuzzy logic can deal with concepts that cannot be expressed as the true or false but partly true. It is more popular due to dealing with problems that have uncertainty, parameter variation, vagueness, and especially whose system model is complex or not accurately define in mathematical terms for the designed control action. It is rules based on membership function relate input variable to output variable.

Fuzzy logic was first proposed by Lotfi A. zadeh of the University of California at Berkeley in a 1965 paper. After that in a 1973 he elaborated on his ideas that introduced the concept of ''linguistic variable''. The fundamental design behind fuzzy logic control is to integrate the 'expert experience' of human in the design of a controller in controlling a procedure whose input and output relationship has described by a set of fuzzy control rules (IF -THEN RULES) involving linguistic variable [L.A. Zadeh, 1968].

5.1 Methodology

To analyze the affecting parameters in water quality we introduce a modern methodology (Fuzzy logic controller) in this paper. It manages and explores the knowledge in this specific application by reasoning on a database of facts by means of suitable inference rules. The fuzzy logic controller system for affecting parameters analysis is divided into four main components: the fuzzification, knowledge base, Inference engine, and the Defuzzification.

Fuzzy logic controller has four components:

a) **Fuzzification:** It transforms input into suitable linguistic value so that, it will compare to the rule in rule base.

b) **Knowledge base:** It has contains the knowledge in form of a set of rules to control the artificial system. It is collection of the rules. The basic function of rule base is to provide the required information to fuzzification module, the rule base and the defuzzification module. 'If' part is known as antecedent and 'then' part is known as consequent [T. J. Ross, 2004]

c) **Inference engine:** If control rules are proper then it decides the input to the plant. The Inference system provides the mechanism for invoking or referring to the rule base such that the proper rules are fired up on the situation.

d) **Defuzzification:** It converts fuzzy output to crisp output [Kwang H. Lee].

Figure-1 shows the basic Fuzzy logic controller components.

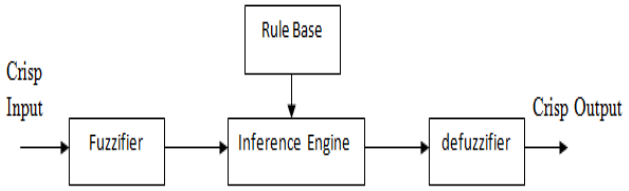


Figure-1. Fuzzy Logic Controller Components.

5.2 Mathematical model formulation

Step: 1 Fuzzification

Table-1. Definition of linguistic variables [IS water specification; 10500, 2012].

Input	Linguistic variable	Qualitative range
Colour	Low	0-10
	Medium	5-15
	High	10-20
pH	Low	0 -7
	Medium	3.5-10
	High	7-14
Turbidity	Acceptable	0-5
	Permissible	2.5-7.5
	unfit	5-10
Total dissolved solid (TDS)	Good	0-1500
	Fair	750-2250
	Bad	1500-3000
Chloride	Low	0-1000
	Medium	500-1500
	High	1000-2000
Calcium	Low	0-200
	Medium	100-300
	High	200-400
Magnesium	Low	0-100
	Medium	50-150
	High	100-200
Sulphate	Low	0-300
	Medium	150-450
	High	300-600
Hardness	Low	0-500
	Medium	250-750
	High	500-1000

5.3 Implementation

In our problem, we use the fuzzy logic controller (FLC) concept to analyze our data. First we convert our parameter into fuzzy sets using Triangular Fuzzy sets (Table-1). Then we design a Fuzzy logic controller and define Fuzzy inference rules for the first four parameter (as inputs) to analyze the quality of water physically (output) and then define Fuzzy inference rules for the next five parameter (as input) to analyze the quality of water chemically (output). Then we define another set of Fuzzy inference rules by using the above two outputs as input and analyze the complete quality of water. Fuzzy rules interact between input and output. Now we are going to use the fuzzy TECH 5.54 d software professional edition to design our fuzzy logic controller. The following diagram will help us to illustrate our discussion. In fuzzy

rules the software helped to show the result and analyze the output performance of affecting parameter of water quality in water treatment plant process.

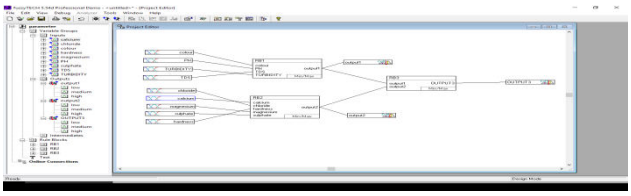


Figure-2. Graphical representations: water quality parameter.

Now we define triangular Fuzzy sets to our input parameters as well as to our output result in the following manner. Figure-3 gives the triangular fuzzy sets for pH values and feasible region and Figure-4 gives the triangular sets for Turbidity values and feasible region.

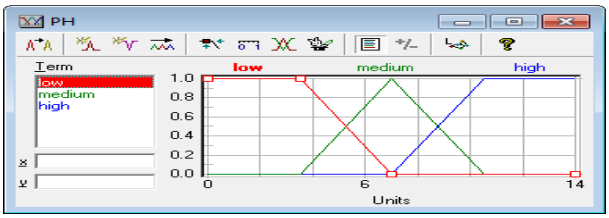


Figure-3. pH values and feasible region.

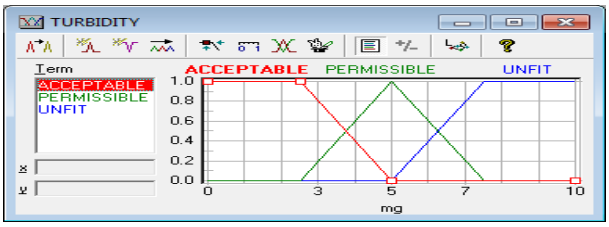


Figure-4. Turbidity values and feasible region.

Step 2: Rule base

State evaluation fuzzy control rules: State variables are in the antecedent part of rules and control variables are in the consequent part. In the case of MISO (Multiple Input Single Output), they are characterized as a collection of rules of the form.

R_1: *if* x *is* A_1 *and* y *is* B_1 *then* z *is* C_1
R_2: *if* x *is* A_2 *and* y *is* B_2 *then* z *is* C_2
....
R_n: *if* x *is* A_n *and* y *is* B_n *then* z *is* C_n

Where x, y and z are linguistic variables representing the process state variable and control variable. A_i, B_i *and* C_i Are linguistic value of the variable x, y and z in the universe of discourse U, V and W . $i = 1,2,3, \dots \dots$
That is $x \in U, A_i \subset U$
$y \in V, B_i \subset V$
$z \in W, C_i \subset W$

In general the consequent part is represented as a function of the state variable $x, \dots . . y$

R_i: *if* x *is* A_i *and* y *is* B_i *then* $z = f_i(x, \dots \dots y)$.

The knowledge base for the parameter includes the following IF THEN rules:

1) IF (Ph is low, TDS fair, Colour is low, Turbidity is acceptable) THEN (water impurities is high).
2) IF (Ph is medium, TDS is fair, Colour medium, Turbidity is permissible) THEN (water impurities is medium).
3) IF (Ph is medium, TDS is fair, Colour medium, Turbidity is permissible) THEN (water impurities is medium).
4) IF (Ph is medium, TDS is good, Colour low, Turbidity is acceptable) THEN (water impurities is low).
5) IF (Ph is high, TDS is bad, Colour high, Turbidity is unfit) THEN (water impurities is high).

Step: 3 Inferences (Mamdani Method)

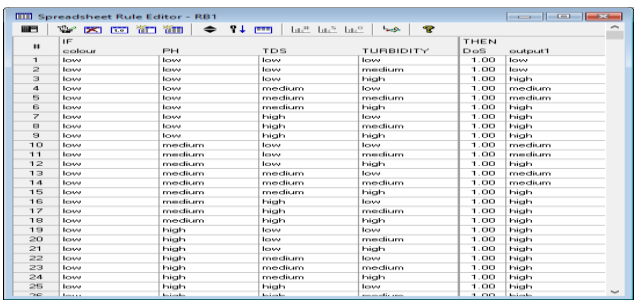
This method uses minimum operator as a fuzzy implication operator. Suppose fuzzy rules are given in the following form [Kwang H. Lee]. R_i: if x is A_i and y is B_i then z is C_i,
I = 1, 2… n
$X \in U, A_i \subset U$
$Y \in V, B_i \subset V$
$Z \in W, C_i \subset W$
When input data are fuzzy sets A' and B'
$\alpha_i = \min [\max(\mu_{A'}(x) \wedge \mu_A(x)), \max(\mu_{B'}(y) \wedge \mu_B(y))]$
$\mu_{Ci'}(z) = \alpha_i \wedge \mu_{Ci}(z)$; i=1,2,3……,n
The aggregate result C' is defined by

$$\mu_{c'}(z) = \bigvee_{i=1}^{n} \left[\alpha_i \wedge \mu_{c_i}(z)\right]$$

$$C' = \cup_{I=1}^{N} C_I'.$$

Now we define the fuzzy inference rules (Rule Block -1 – RB1) to the first four parameters mentioned in the table no -1 as inputs with the quality of the water as output in the following way using Mamdani method.

Table-2. Output result from the application of IF –THEN rules,with membership function.

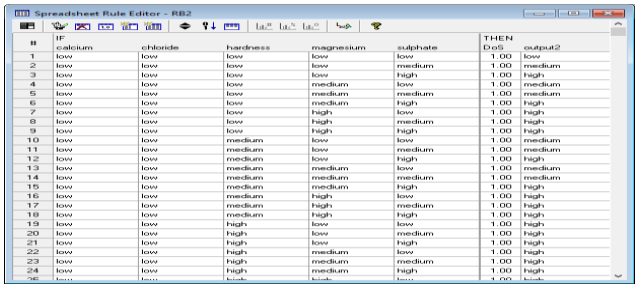


Spreadsheet Rule Editor - RB1

#	IF colour	PH	TDS	TURBIDITY	THEN DoS	output1
1	low	low	low	low	1.00	low
2	low	low	low	medium	1.00	low
3	low	low	low	high	1.00	high
4	low	low	medium	low	1.00	medium
5	low	low	medium	medium	1.00	medium
6	low	low	medium	high	1.00	high
7	low	low	high	low	1.00	high
8	low	low	high	medium	1.00	high
9	low	low	high	high	1.00	high
10	low	medium	low	low	1.00	medium
11	low	medium	low	medium	1.00	medium
12	low	medium	low	high	1.00	high
13	low	medium	medium	low	1.00	medium
14	low	medium	medium	medium	1.00	medium
15	low	medium	medium	high	1.00	high
16	low	medium	high	low	1.00	high
17	low	medium	high	medium	1.00	high
18	low	medium	high	high	1.00	high
19	low	high	low	low	1.00	high
20	low	high	low	medium	1.00	high
21	low	high	low	high	1.00	high
22	low	high	medium	low	1.00	high
23	low	high	medium	medium	1.00	high
24	low	high	medium	high	1.00	high
25	low	high	high	low	1.00	high

Now we define the fuzzy inference rules (Rule Block -2 -RB2) to the next five chemical parameters mentioned in the table no -1 as inputs with the quality of the water as output in the following way using Mamdani method

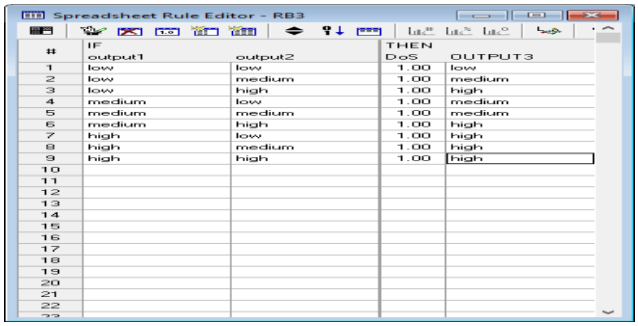
Table-3. Analyses of water quality output values.



#	IF calcium	chloride	hardness	magnesium	sulphate	THEN DoS	output2
1	low	low	low	low	low	1.00	low
2	low	low	low	low	medium	1.00	medium
3	low	low	low	low	high	1.00	high
4	low	low	low	medium	low	1.00	medium
5	low	low	low	medium	medium	1.00	medium
6	low	low	low	medium	high	1.00	high
7	low	low	low	high	low	1.00	high
8	low	low	low	high	medium	1.00	high
9	low	low	low	high	high	1.00	high
10	low	low	medium	low	low	1.00	medium
11	low	low	medium	low	medium	1.00	medium
12	low	low	medium	low	high	1.00	high
13	low	low	medium	medium	low	1.00	medium
14	low	low	medium	medium	medium	1.00	medium
15	low	low	medium	medium	high	1.00	high
16	low	low	medium	high	low	1.00	high
17	low	low	medium	high	medium	1.00	high
18	low	low	medium	high	high	1.00	high
19	low	low	high	low	low	1.00	high
20	low	low	high	low	medium	1.00	high
21	low	low	high	low	high	1.00	high
22	low	low	high	medium	low	1.00	high
23	low	low	high	medium	medium	1.00	high
24	low	low	high	medium	high	1.00	high

Now we define the fuzzy inference rules (Rule Block -3 -RB3) to the parameters, physical and chemical as inputs with the complete quality of the water as output in the following way using Mamdani method.

Table-4. Analyses of water quality output values.



#	IF output1	output2	THEN DoS	OUTPUT3
1	low	low	1.00	low
2	low	medium	1.00	medium
3	low	high	1.00	high
4	medium	low	1.00	medium
5	medium	medium	1.00	medium
6	medium	high	1.00	high
7	high	low	1.00	high
8	high	medium	1.00	high
9	high	high	1.00	high

Step: 4 Defuzzification

Defuzzification is processes to get an output value that represent the quality of water [Kwang H. Lee] by the method called Centre of Area (COA) Method.

The widely used COA strategy generates the centre of gravity of the possibility distribution of a fuzzy set C. The method gives

$$Z_0 = \frac{\sum_{j=1}^{n} \mu_c(z_j).z_j}{\sum_{j=1}^{n} \mu_c(z_j)}.$$

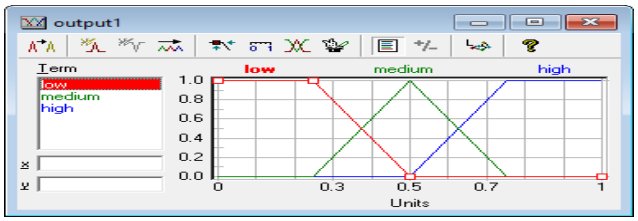


Figure-5. Graph of water quality output values.

In this above figure the first four parameter as input values.It shows the out put result.

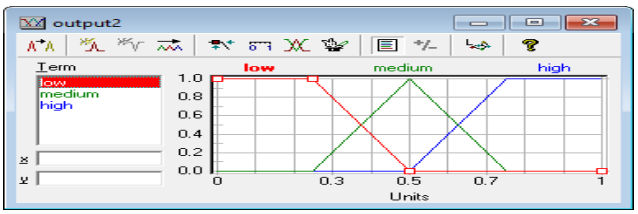


Figure-6. Graph of water quality output values.

In this above figure the chemical parameter as input values. It shows the out put result.

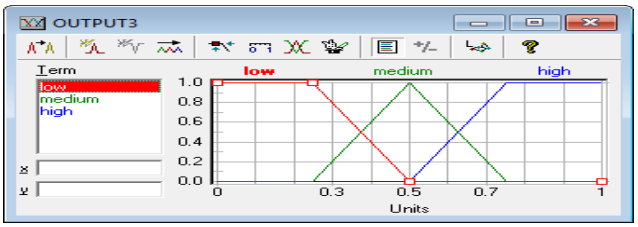


Figure-7. Graph of water quality output values.

6. RESULTS AND DISCUSSIONS

The simulation and results are carried out in Fuzzy tech 5.54d. This paper simulates the parameters helpful to identify the quality of water.

In the below Figure-8, the values in left column are colour, turbidity, ph are the physical parameter and TDS, sulphate, magnesium, chloride, hardness, calcium are the chemical parameter given as input values. The turbidity value with in unfit limit, we get the value of output-1 is 0.8750 and the value of output -2 is 0.8546 and the value of output-3 is 0.8750 which represent impurities level are high.

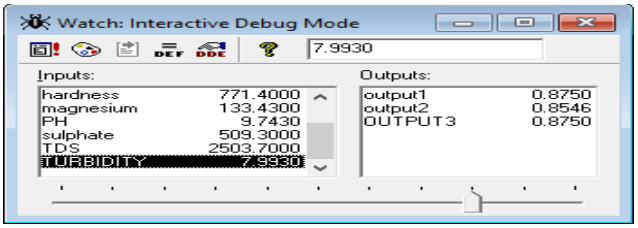


Figure-8. Effect of multiple parameter variation on water impurities.

Figure-9 show if the turbidity value with in permissible limit, we get the value of output 1 is 0.6380 and the value of output 2 is 0.5322 and the value of output 3 is 0.6380 which represent the quality of water. It shows changes in the value of the parameter affect the quality of water as well the treatment process. In the same manner we can place any number of inputs using the Fuzzy TECH 5.54 d and obtain the meaningful result. The main advantage of using this software is, if we want to include,exclude the parameters from the system then that can be done in simple steps and also it has a lot of option to analyze the parameter in different fuzzification and defuzzification methods .

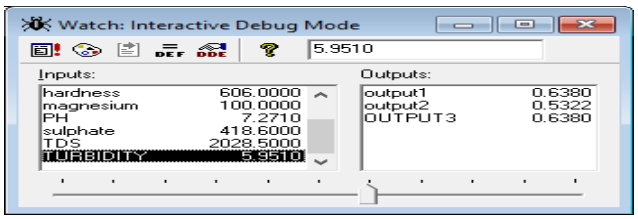


Figure-9. Effect of multiple parameter variation on water impurities.

7. CONCLUSIONS

From the calculated standard value, physical and chemical parameters of raw water was analysed using the fuzzy TECH5.54d software .The turbidity parameter was chosen specifically for analysis, the standard turbidity values of raw water was studied in the acceptable , permissible, unfit limits, it was calculated that variation in the input turbidity values affected the output values ,thereby determining the quality of water .Using the fuzzy tech 5.54d software n number of water quality parameter can be further studied.

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