Application of Fuzzy Logic to Determine Water Quality of Tapi River

Prof. Payal Zaveri[1], Urvi Parekh[2]

Abstract*: The specific significance of Tapi River within the ponder of superficial aquatic contamination since municipal sewage, rural and urban overspill are released into it conveying almost significant alter in the water quality. This research was pointed at utilizing the application of Water Quality Index(WQI) along with FuzzyTECH software in evaluating the quality of Waterway Tapti for open utilization. In this study, Fuzzy Logic System was intended to offer the circumstances required for determining water quality. For this purpose, physic-chemical properties of Tapi River have been studied and used for successful operation of Fuzzy Logic System to evaluate more useful and reliable water quality index. In this syatem, pH, DO and Turbidity were used as input parameters to get output parameter as water quality index. The results when compared to WHO permissible limits indicated that the river was contaminated and water is unsafe for native usage and requires additional treatment.

***Keywords*: Fuzzy Logic, Physico-chemical properties, Tapi River, Water Quality Index**

I. INTRODUCTION

Fuzzy logic may be a shape of many-esteemed rationale in which the reality estimations of factors might be somewhere in the range of 0 and 1. It is utilized to handle the concept of midway truth, where the truth esteem may extend between totally genuine and totally wrong. By differentiate, in Boolean rationale, the reality estimations of factors may as it were be the numbers esteems 0 or 1.

Fuzzy logic is an approach to computing based on "degrees of truth" instead of the regular "genuine or untrue" (1 or 0) Boolean rationale on which the advanced computer is based.

The thought of fuzzy logic was to begin with progressed by Dr. Lotfi Zadeh of the College of California at Berkeley within the 1960s. Dr. Zadeh was working on the issue of computer understanding of common dialect. Common dialect (like most other exercises in life and indeed the universe) isn't effortlessly interpreted into the supreme terms of 0 and 1. It may offer assistance to see fuzzy rationale as the way thinking truly works and parallel or Boolean rationale is essentially a extraordinary case of it.

Fuzzy logic incorporates 0 and 1 as extraordinary cases of truth (or "the state of things" or "reality") but moreover incorporates the different states of truth in between so that, for illustration, the result of a comparison between two things may be not "tall" or "brief" but ".38 of tallness." Fuzzy rationale appears closer to the way our brains work.

The information and frame a number of fractional truths which we total advance into higher truths which in turn, when certain

limits are surpassed, cause certain advance comes about such as engine response. A comparable kind of prepare is utilized in neural systems, master frameworks and other fake insights applications. Fuzzy logic is fundamental to the improvement of human-like capabilities for AI, now and then alluded to as counterfeit common insights: the representation of generalized human cognitive capacities in computer program so that, confronted with an new errand, the AI framework may discover a arrangement.

A. *Linguistic Variables:*

Though factors in science guideline speaking receipts scientific qualities, in fuzzy logic applications, non-numeric values are frequently consumed to inspire the appearance of rules and facts. A phonetic variable such as age may acknowledge values such as youthful and its antonym ancient. Since regular tongues don't constantly contain enough worth terms to exact a fuzzy regard scale, it is normal sharpen to alter phonetic qualities with elucidating words or intensifiers.

For case, able to utilize the supports or maybe and to some degree to develop the extra values or maybe ancient or to some degree youthful. Fuzzification activities can outline numerical information esteems into fuzzy enrollment capacities. And the inverse de-fuzzifying activities can be utilized to outline a fuzzy yield participation capacities into a "fresh" yield esteem that can be at that point utilized for choice or control purposes.

B. *Applications:*

• Fuzzy rationale is greatly valuable for numerous individuals included in inquire about and advancement counting engineers (electrical, mechanical, respectful, chemical, aviation, rural, biomedical, computer, natural, geographical, mechanical, and mechatronics), mathematicians, computer program engineers and analysts, characteristic researchers (science, chemistry, soil science, and material science), restorative analysts, social researchers (financial matters, administration, political science, and brain research), open approach examiners, trade examiners, and legal scholars.

• Fuzzy logic has been utilized in various applications such as facial design acknowledgment, discuss conditioners, washing machines, vacuum cleaners, antiskid braking frameworks, transmission frameworks, control of metro frameworks and unmanned helicopters, knowledge-based frameworks for multiobjective optimization of control frameworks, climate estimating frameworks, models for unused item estimating or venture hazard evaluation, restorative determination and treatment plans, and stock exchanging.

• It has been effectively utilized in various areas such as control frameworks designing, picture handling, control designing, mechanical robotization, mechanical autonomy, buyer hardware, and optimization. This department of arithmetic has ingraining unused life into logical areas that have been torpid for a long time.

C. *Applications in Environmental Engineering:*

- Water Engineering
  - To check the ground water vulnerability
  - To decide the type of water treatment giving to the water body
  - To optimise cost in Water Distribution Network
- Wastewater Engineering
  - To plan control techniques to keep the method in good working condition
  - Comparison of input and yield datas for each unit
  - To estimate wastewater Index
- Solid Waste Management
  - To allocate best landfill site
  - To give preference of treatments
- Hazardous Waste Management
  - To give ranking to the treatment
- Air Pollution
  - To calculate Air Quality Index
- Noise Pollution
  - Effects of noise pollution on speech interference

D. *Advantages:*

- Easy to comprehend, check and uphold
- Informal to be prototyped
- They function even when there is absence of rules or wrong rules
- Combination of linguistic and numeric
- Reasoning process is simple so saving the computing power
- Less time require to develop a model than conventional.

E. *Drawbacks:*

- More tests and simulation are required
- Not easily learned
- Difficult to set up rectify rules
- Lack of exact numerical model

II. WATER QUALITY INDEX (WQI)

Water Quality Index, which was developed in the early 1970s, gives an indication of the health of the water bodies at various points and can be used to keep a track of water quality over a period of time. To calculate the water quality index various physico–Chemical parameters should be studied in detail and then their experimental values are substituted in the mathematical expression.
Water Quality Index is a method to express the water quality according to the degree of purity. It is now widely used in scientific studies by using the physico – chemical parameters. The WQI was calculated by using the following equation:

$$WQI = \frac{\sum WiQi}{\sum Wi}$$

Where, Qi = quality rating, Wi = Unit weight
The quality rating scale (Qi) for each parameter is calculated by using the expression:

$$Qi = \frac{Vactual - Videal}{Vstandard - Videal} \; x\,100$$

Where, V_{actual} is estimated concentration of i^{th} parameter in the analysed water
V_{ideal} is the ideal value of this parameter in pure water
V_{ideal} = 0 (except pH =7.0 and DO = 14.6 mg/l)
$V_{standard}$ is recommended standard value of i^{th} parameter
The unit weight (Wi) for each water quality parameter is calculated by using the following formula :

$$Wi = \frac{K}{Si}$$

Where, K= proportionality constant and is taken as unity.

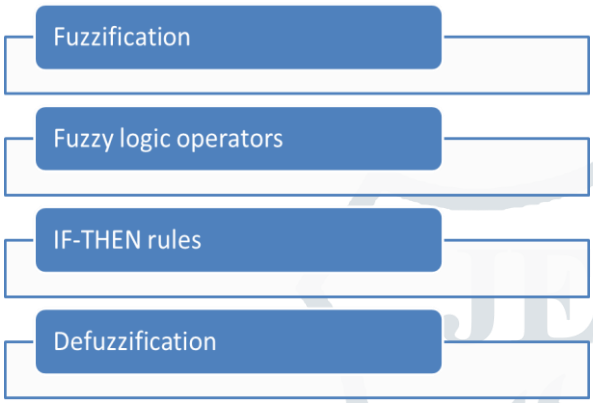
III. METHODOLOGY

Study Area: Tapi Stream at its beginning in Multai Dist.,Betul, M.P. It encompasses a add up to length of around 724 km and seepage region of 30,000 sq.km. for the final 32 km of its course and its length.

Table 1: Physico-Chemical properties to calculate water quality index of Tapi river

Parameters	Lowest	Extreme	Mean
pH	6.9	7.5	7.2
DO	3.2	5.3	4.25
Turbidity	29	35	32

All units are in mg L^{-1} except pH.



i. All input values are fuzzified into fuzzy membership functions.
ii. All appropriate standards are executed in the standard base to process the fuzzy output functions.
iii. The fuzzy output functions are de-fuzzified to get "fresh" yield esteems.

A. *Fuzzification:*

Fuzzy sets are often described as triangle or trapezoid-formed curves, as each regard will have a incline where the esteem is expanding, a top where the esteem is break even with to 1 (which can have a length of or more noteworthy) and a inclination where the esteem is decreasing. They can also be portrayed utilizing a sigmoid function.[8] One common case is the standard calculated work characterized as

S(x)= 1/(1+e^(-x))

which has the accompanying evenness property

S(x)+ S(-x)= 1

From this it follows that

[S(x)+ S(-x)].[S(y)+ S(-y)].[S(z)+ S(-z)]= 1

B. *Fuzzy Logic Operators:*

Fuzzy rationale works with enrollment values in a way that mirrors Boolean logic.

To this conclusion, substitutions for essential administrators AND, OR, NOT must be accessible. There are a few ways to this. A common substitution is called the Zadeh operators:

Boolean	AND (x,y)	OR (x,y)	NOT(x)
Fuzzy	MIN (x,y)	MAX (x,y)	1-x

For TRUE/1 and FALSE/0, the fuzzy expressions deliver the same result as the Boolean expressions. There are moreover other administrators, more phonetic in nature, called fences that can be connected. These are for the most part intensifiers such as exceptionally, or to some degree, which alter the meaning of a set employing a numerical equation.

However, an self-assertive choice table does not continuously characterize a fuzzy rationale work. Within the paper, a measure has been defined to recognize whether a given choice table characterizes a fuzzy rationale work and a basic calculation of this work blend has been proposed based on presented concepts of constituents of least and greatest. A fuzzy logic work speaks to a disjuncture of constituents of minimum, where a constituent of least could be a combination of factors of the current region more prominent than or equal to the work esteem in this range (to the correct of the work esteem within the disparity, counting the work value).

- Steps to be followed :

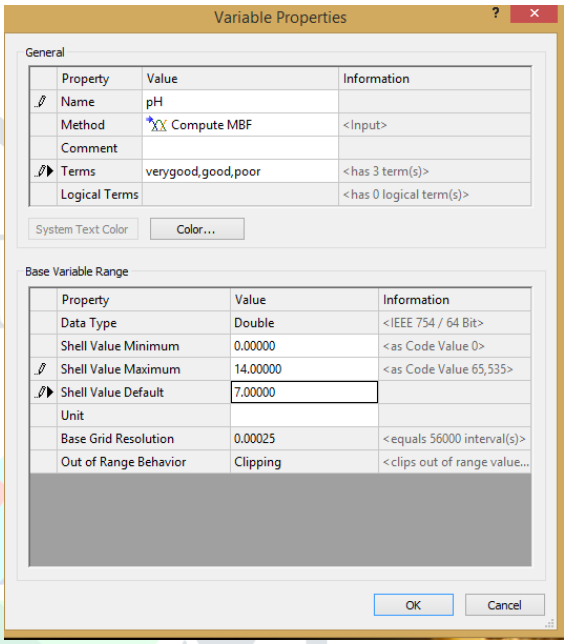


Fig. 1 : Linguistic Variables – Inputs (pH)

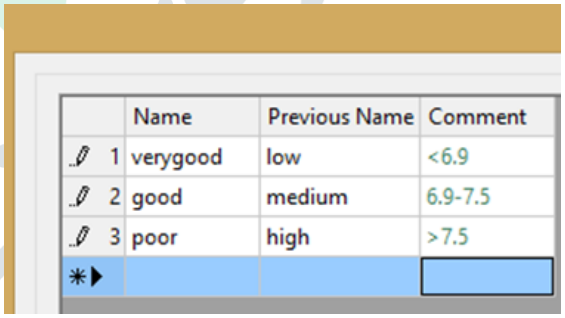


Fig. 2 : Input (pH) Terms

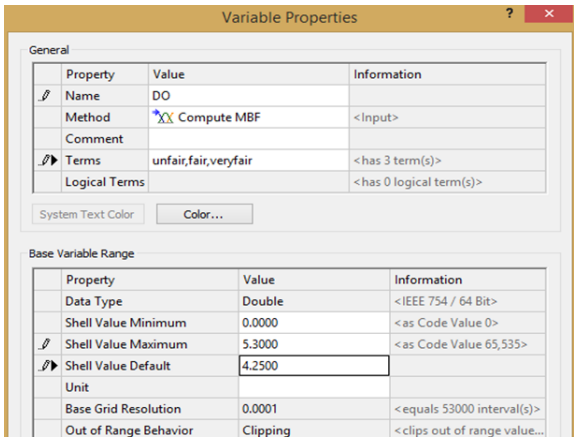


Fig. 3 : Linguistic Variables – Inputs (DO)

	Name	Previous Name	Comment
1	unfair	low	<3.2
2	fair	medium	3.2-5.3
3	veryfair	high	>5.3
*			

Fig. 4 : Input (DO) Terms

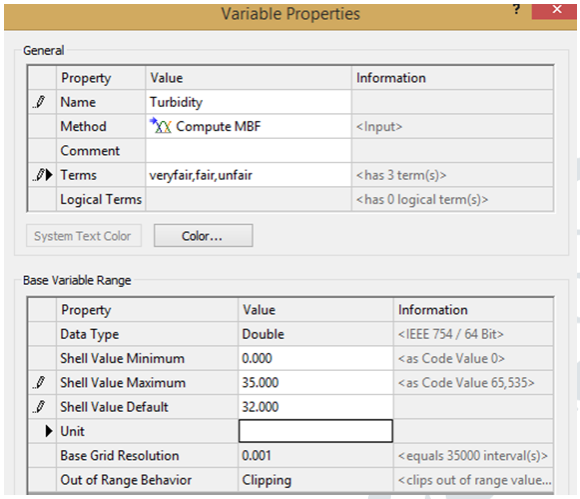


Fig. 5 : Linguistic Variables – Inputs (Turbidity)

	Name	Previous Name	Comment
1	veryfair	low	<29
2	fair	medium	29-35
3	unfair	high	>35
*			

Fig. 6 : Input (Turbidity) Terms

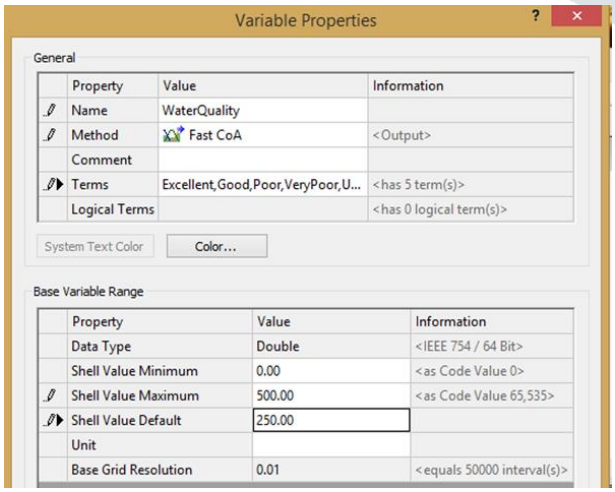


Fig. 7 : Linguistic Variables – Outputs

	Name	Previous Name	Comment
1	Excellent	low	<50
2	Good	medium	50-100
3	Poor	high	100-200
4	VeryPoor	<New>	200-300
5	Unsuitablef...	<New>	>300
*			

Fig. 8 : Output Terms

The range of values for various categories of output variable is provided in Fig.8.

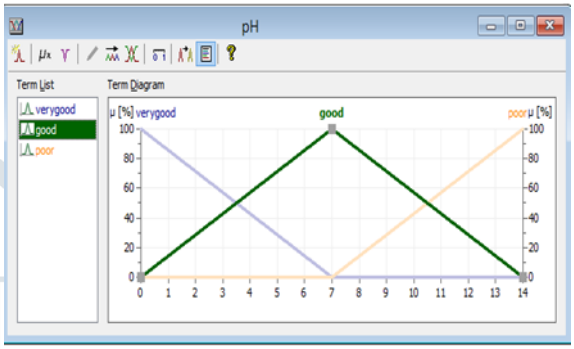


Fig.9 (A) : pH membership function

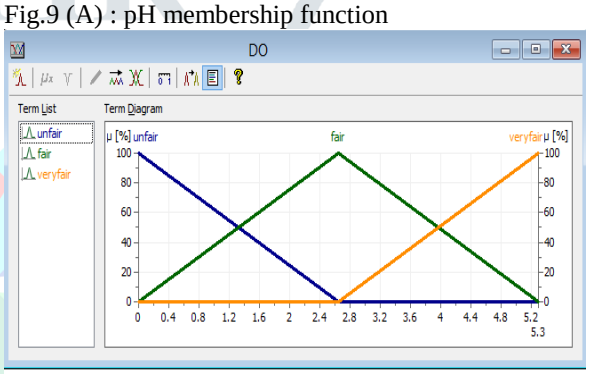


Fig.9 (B) : DO membership function

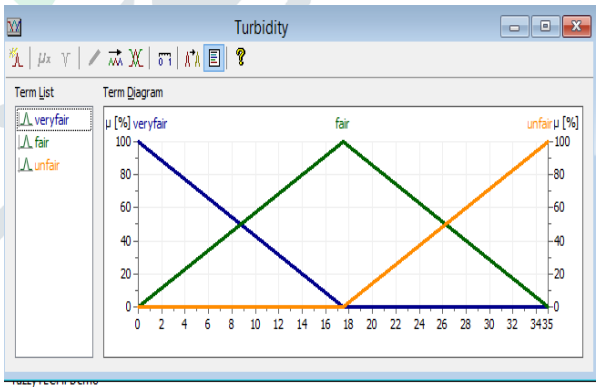


Fig.9 (C) : Turbiditymembership function

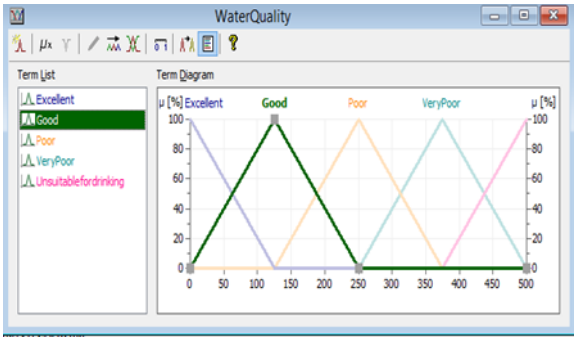


Fig.9 (D) : WQI membership function

Fig.9 (A), (B), (C) and (D) represents the input variables (pH, DO and Turbidity) and output variable (WQI) with their associated membership functions. Membership functions are used to translate the real word values to fuzzy values and back.

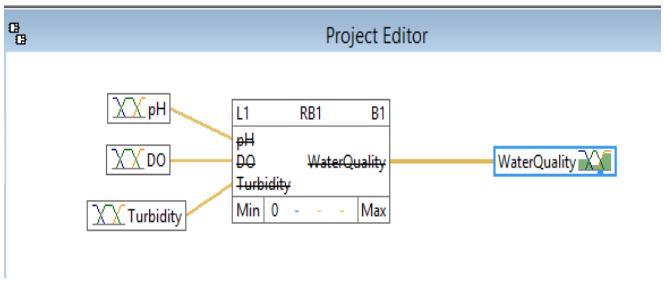


Fig. 10 : Fuzzy Rule Block

Fig.10 illustrates the design and developed fuzzy logic controller to determine water quality of Tapi river. This rule block provides relationship between input variables and output variables. There are three input variables- pH and DO (Chemical parameters) and Turbidity (Physical property) and output variable is Water Quality Index.

C. *IF-THEN Rules:*

IF-THEN rules summarize input or figured certainty standards to desired produced truth values.

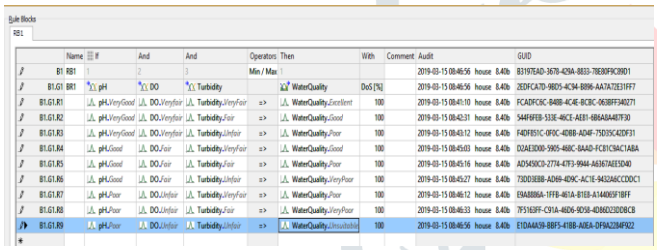


Fig. 11 : IF-AND-THEN Rules

Should an output variable occur in several THEN parts, then the values from the respective IF parts are combined using the OR operator.

D. *Defuzzification:*

The objective is to induce continuous variable from fuzzy certainty values.
This would be straightforward if the created assurance esteems were explicitly those obtained from fuzzification of a given number. Meanwhile all produced certainty values are figured individually, in most cases they don't state to such a set of numbers. At that point, one has to choose for a number that equals best the "deliberate" encrypted within the truth approval.
A common calculation is
1. Cut the input work at this value for each truth approval.
2. The impending about bends are united operating the OR operator
3. The center-of-weight of the area is to be found beneath the curve
4. The x position of the center is at the critical output point.

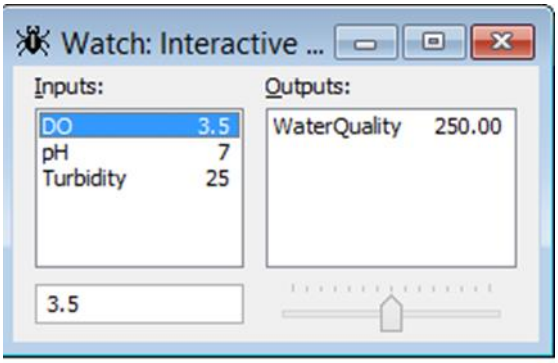


Fig. 12 : Fuzzy Truth Values

Fig.12 shows the fuzzy truth values of input and output variables. When the DO value is 3.5mg/l, pH is 7 and Turbidity is 25 NTU, at that time obtained water quality index is 250.

IV. RESULTS

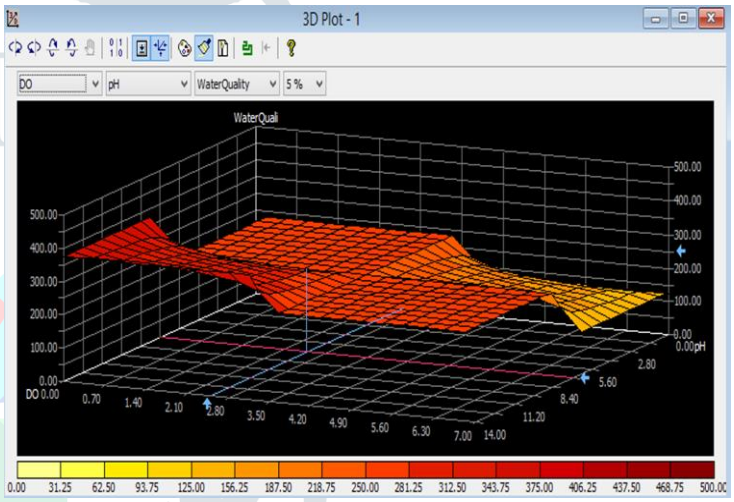


Fig. 13 : 3D Plot between inputs (DO and pH) and output (WQI)

Fig.13 depicts the 3D plot indicating the output variable as a function of two input variables consecutively.

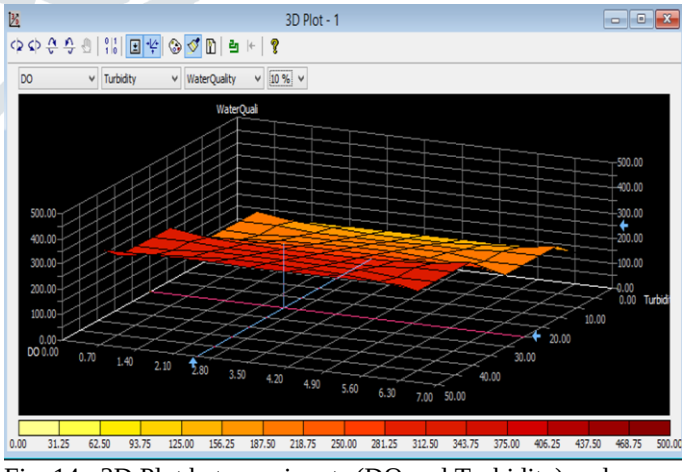


Fig. 14 : 3D Plot between inputs (DO and Turbidity) and output (WQI)

From Fig.14, it is observed that when the DO value is nearly 2.6 and Turbidity is 25 NTU, the obtained water quality index is 250 indicating very poor quality of water.

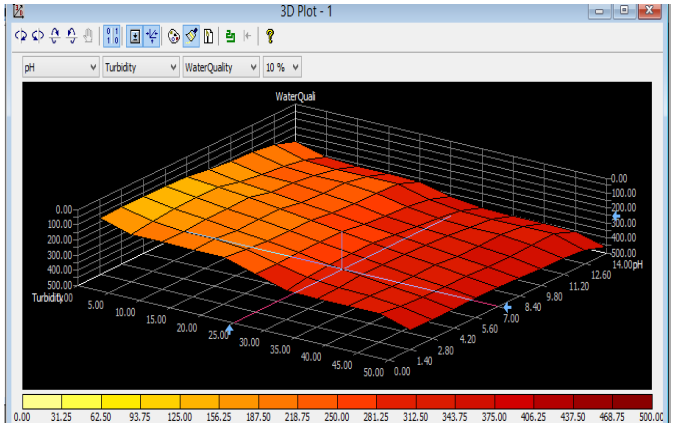


Fig. 15 : 3D Plot between inputs (pH and Turbidity) and output (WQI)

From Fig.15, it is observed that when the value of pH is 7 and Turbidity is 25 NTU, the obtained water quality index is 250 indicating very poor quality of water

V. CONCLUSIONS

• Application of Water Quality Index(WQI) in this consider has been found valuable in evaluating the by and large quality of water and to urge freed of judgment on quality of the water.
• This strategy shows up to be more efficient and gives comparative assessment of the water quality of inspecting stations.
• It is additionally supportive for public to get it the quality of water as well because it is being a valuable instrument in numerous ways within the field of water quality management.
• The approach of fuzzy logic a delicate computing strategy may well be distant a much better representation of a energetic framework and subsequently giving a modern measurement of evaluating waterway water quality for particular purposes.
• The fuzzy logic may be a driving to a more convenient tuned forecast model.
• Thus Fuzzy Logic can be effectively applicable in Environmental Engineering.

REFERENCES

1. BARDOSSV, A., BOOARDI, I., and DUCKSTEIN, L., 1990, Fuzzy regression in hydrology. *Water Resources Research*, 26, 1497-1508.
2. Chang, N. B., and Chen, V. L. (1995). "A fuzzy interval multiobjective programming approach for metropolitan solid waste management system planning." Fuzzy Sets and Sys., in press.
3. Deshpande, A. W, Raje, D.V and Khanna, P; Fuzzy Description of River Water Quality, paper for International conference-EUFIT 1996.
4. Deshpande,A.W, Raje, D.V; and Khanna, P; Agreement Index for Water Consumption, Paper for International Conference-EUFIT 1996 368
5. E. H. Mamdani and S. Assilian, “An experiment in linguistic synthesis with a fuzzy logic controller,” International Journal of Man-Machine Studies, vol. 7, no. 1, pp. 1–13, 1975.
6. Ersoy K and Cho, S; An algorithm to compute the degree of match in fuzzy systems, Journal of Fuzzy Sets and Systems,(l992) North Holland, Vol.49.pp.285- 299.
7. GAJANAND THAKRE, NEELESH SHRIVASTAVA and P. K. MISHRA, 2011, Analytical Studies On Water Quality Index Of River Tapti. Int. J. Chem. Sci.: 9(3), 1401-1409.
8. HESHMATY. B., and KANDEL, A.• 1985, Fuzzy linear regression and its applications to forecasting in environment. Fuzzy Sets and Systems, 15, 159-191.
9. Jigna Desai And Tank.S.K, 2010, Water Quality Index (Wqi) Of River Tapti-Surat, Gujarat-India. Linnaeus ECO-TECH ´10, Kalmar, Sweden, November 22-24.
10. JUANG, C. H., HUANG, X. H., and HOLTZ. R. D., 1992, Determination of fuzzy relationship by fuzzy regression, Civil Engineering Systems. 9, 299-318.
11. OH, S. B., KIM, W., and LEE, J. K., 1992, An approach to causal modeling in fuzzy environment and its application. Fuzzy Sets and Systems, 51,179-188.
12. R. M. Tong, The Construction and Evaluation of Fuzzy Models in Advances in Fuzzy Set Theory and Applications, Edited by M. M. Gupta, R. K. Ragade, R. R. Yager, North-Holland,Amsterdam, The Netherlands, 1979.