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An ANN Model for River Water Quality Management Using Fuzzy Techniques - (A Case Study of Yaba River in Kacha)

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Abstract: Proper assessment of water quality status in a river system is an essential task for meeting the goals of environmental management basin. However, a discrepancy frequently arises from the lack of a clear distinction between each water utilization mode, the uncertainty in the quality criteria of water employed and vagueness or fuzziness embedded in the decision making output values. Owing to inherent imprecision, difficulties always exist in some conventional methodologies like water quality index (WQI) when describing integrated water quality conditions with respect to various chemical constituents, biological aspects, nutrients, and aesthetic qualities such as Dissolved Oxygen (D.O.), Biochemical Oxygen Demand (B.O.D.), Temperature, Therefore, in this study, a methodology based on Fuzzy Inference Systems (FIS) would be use to assess water quality of water under the study.
Keywords: ANN Model, Water Quality, Fuzzy Technique, water quality index

I. INTRODUCTION

A. Background of Study

River water quality management has become an important issue in public policies throughout the world. More than governments are concerned about the quality of their environmental resources because of the complexity of water quality data sets Many countries have introduced a scheme for river water quality monitoring and Assessment, examining separate stretches of fresh water in terms of their chemical, biological and nutrient constituents and overall aesthetic condition. General indices are used as comprehensive evaluation instruments to help assess conditions at the earliest stage to clarify monitoring priorities for regulatory agencies dealing with pollution abatement problems. In this study, the fuzzy logic formalism would be used to access River water quality by developing a water quality index (WQI) based on fuzzy reasoning. Fuzzy logic can be considered as a language that allows one to translate sophisticated statements from natural language into a mathematical formalism. Fuzzy logic can deal with highly variable, linguistic, vague and uncertain data or knowledge and therefore, has the ability to allow a logical, reliable and transparent information stream from data collection to data usage in environmental applications. The Fuzzy logic would be use to assess water quality by developing a water quality index based on fuzzy reasoning Fuzzy logic provides a framework to model uncertainty, the human way of thinking, reasoning, and the perception process. Fuzzy systems were first introduced by Professor (Lotfi Zadeh,1965) The fuzzy logic can be used for mapping inputs to appropriate outputs. Fuzzy logic is suitable to be used in developing environmental indices because it has the ability to deal with nonlinear, uncertain, ambiguous, and subjective information. In river water management, a lot uncertainty is involved, especially from the random nature of hydrologic variables (temperature, stream flow, etc.), fuzziness related to goals of the dischargers and pollution control agencies, and uncertainty under partial ignorance.

B. Study Area

Katcha town in Katcha local government area of Niger state situated along the bank of Yaba river which is tributary of river Niger. According to the history Katcha drive it name from the main preoccupation of the origins, which was basket weaving known in Nupe speaking language as “Kasa”

The same raw materials was used for fishing which later become one of the major occupation of the people (Ndagiman, 2010).

Yaba River is the major source of the water in Katcha and is located in the riverine area popularly known as Kpata in nupe language.

C. Problem Statement

Environmental pollution such as water pollution is one of the causes of health challenges face by the masses so also, some animals living inside the water are dying because of water pollution. Therefore, there is need for proper investigation about the water quality used by masses these include determination of pH value, Temperature, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and Turbidity of water we use for our day to day activities for proper hygiene.

D. Aim and Objectives

The prime aim of this study is to assess the quality of water management, based on the above the following are the specific objectives of the study:

1) To collect sample water from Yaba River and predict the water quality index (WQI) for proper hygiene
2) To create a model to ensure that river pollution can be controlled and reduced.

II. LITERATURE REVIEW

A. Introduction

This chapter provides the review of some of the river water quality techniques that have been used in the detection of river water quality such as physical, biological and chemical quality.

B. Fuzzy Techniques

The application of artificial intelligence approach from the perspective of fuzzy logic reasoning system can serve as an idea of combining human thinking and reasoning in the prediction of transaction fraud in an uncertain situation (Bingyi, Yong, Rehan and Sankaran, 2012).

C. Fuzzy Inference System

Fuzzy inference is the process of formulating the mapping from a given input determinant to an output determinant using fuzzy logic reasoning. Decisions can be made on basis of mapping, or patterns discerned. The fuzzy inference process involves three crucial steps: membership functions, fuzzy set operations, and inference rules (Md. Pauzi Abdullah, *et al.*, 2008).

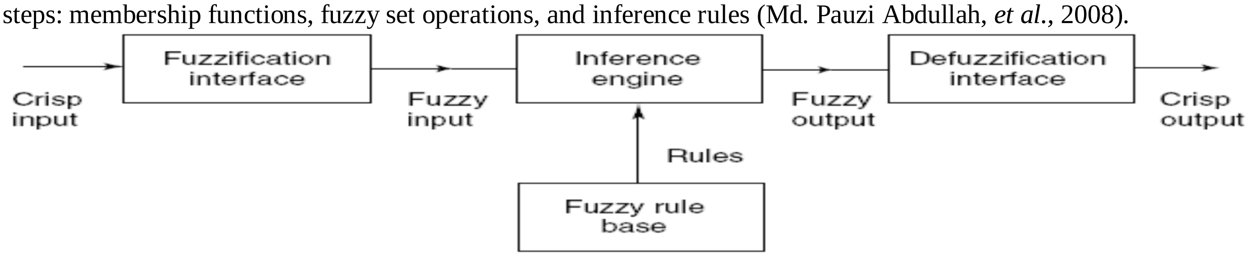

Figure 1: Basic Architecture of Fuzzy Inference System.

D. Membership Function by Water Quality Classification

Abdullah, *et al.*, (2008) a membership function is a curve that defines how each point in the input space is mapped to a membership value between 0 and 1. The input space is called the universe of discourse. The output-axis is called the membership value μ. If X is the universe of discourse and its elements are denoted by x, then a fuzzy set A is defined as a set of ordered pairs.

$$A = \{x, \mu_A(x) | x \in x\} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots i$$

Where $\mu_A(x)$ is the membership function of x in A. A membership function is an arbitrary curve whose shape is defined by convenience. The standard fuzzy set operations are: union (OR), intersection (AND) and additive complement (NOT).

They manage the essence of fuzzy logic. If two fuzzy sets A and B are defined on the universe X, for a given element x belonging to X, the following operations can be carried out:

(Intersection, AND) $\mu A \cap B(x) = min(\mu_A(x), \mu_B(x)) \dots\dots\dots ii$

(Union, OR) $\mu A \cup B(x) = max(\mu_A(x), \mu_B(x)) \dots\dots\dots\dots\dots\dots iii$

(Additive Complement, NOT) $\mu\overline{A}(x) = 1 - \mu_A(x) \dots\dots\dots\dots\dots iv$

The third concept is the inference rule. An if–then rule has the form: “If x is A then z is C”, where A and C are linguistic values defined by fuzzy sets in the universes of discourse X and Z, respectively. The if–part is called the antecedent, while the then–part is called the consequent.

E. Fuzzy Sets

Zadeh, 1975 introduce the theory of fuzzy sets was first introduced to model uncertainty in subjective information. Fuzzy sets are defined as sets whose members are vague objects. Data can generally be received in terms of linguistic judgments and beliefs (natural language), which can then be converted to the form of fuzzy sets in order to provide a base for logical and mathematical reasoning (L. A. Zadeh,1975). A fuzzy set is represented by a membership function defined on the universe of discourse.

F. Fuzzification

Fuzzification is the process of decomposing a system input and/or output into one or more fuzzy sets. Many types of curves can be used, but triangular or trapezoidal shaped membership functions are the most common. In this present study triangular functions were utilized for input/ output variables. Fuzzy sets span a region of input (or output) value graphed with the membership.

G. Defuzzification

After fuzzy reasoning a linguistic output variable which needs to be translated into a crisp value. The objective is to derive a single crisp numeric value that best represents the inferred fuzzy values of the linguistic output variable. Defuzzification is such inverse transformation which maps the output from the fuzzy domain back into the crisp domain.

H. Fuzzy Model in River Quality Assessment

A fuzzy model for river water quality assessment has been developed. Different shapes of membership functions can be used, depending upon the type of application (Pedrycz W., *et al.*,1992) . The right prediction of the fuzzy model depends on the number of fuzzy sets used in the mapping process, since it facilitates more continuity to the universe of discourse. However, in this research, each of the six input quality determinants have been divided into three categories, and trapezoidal membership functions were assigned. It has chosen ADE (adequate), ACC (acceptable), HAC (highly acceptable) fuzzy sets for inputs determinants, and for the output determinant. Functions were derived from the parameters given in Table below.

Three fuzzy sets to split the input and output have been considered Suitable for scope of this study. The amount of overlap, the width and the shape of fuzzy sets should be considered by an expert for each input variable. Ranges for fuzzy sets were based on interim national quality standards (INWQS) for Malaysia. Malaysian rivers are classified in the interim national water quality standards (INWQS) for Malaysia based on water quality criteria and standards for several beneficial uses. Ranges and parameters of quality determinants in the fuzzy inference system were given in Table **1**. Six quality determinants have been selected to evaluate water quality by means of an aggregated index called FWQ index. In the fuzzy algorithm, the Mamdani approach is used. Fuzzy inference of the determinants is determined using grades of membership functions of the parameters. In the same way, other rules can be enunciated. Robustness of the system depends on the number and quality of the rules.

ADE: Adequate
ACC: Acceptable
HAC: Higher Acceptable.

Table 1. Parameters for Membership Functions in the Fuzzy Inference System

Determinant	Units	Adequate ADE				Acceptable ACC				Highly Acceptable HAC				Range
		a	b	c	d	a	b	c	d	a	b	c	d	
DO	mg/L	.13	-0.13	.36	.50	.36	.48	.76	.87	.79	.85	1.07	1.13	0-1
BOD	mg/L	-.45	-.05	.13	.20	.13	.23	.42	.50	.36	.52	1.07	1.47	0-1
COD	mg/L	-.45	-.05	.13	.23	.13	.21	.35	.50	.38	.50	1.02	1.02	0-1
SS	mg/L	-.04	-.03	.04	.07	.04	.06	.13	.16	.13	.15	1.12	1.52	0-1
pH	mg/L	0	0	.77	.78	.75	.81	.90	.92	.88	.94	1.01	1.04	0-1
NH_3-N	mg/L	0	0	.083	.089	.06	.12	.14	.41	.33	.48	1.01	1.01	0-1
FWQ		0	0	.56	.66	.58	.65	.82	.86	.78	.86	1.05	1.07	0-1

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III. RESEARCH METHODOLOGY

A. Design Methodology

This section provides a step by step guide using Fuzzy Logic system. The details are as shown in

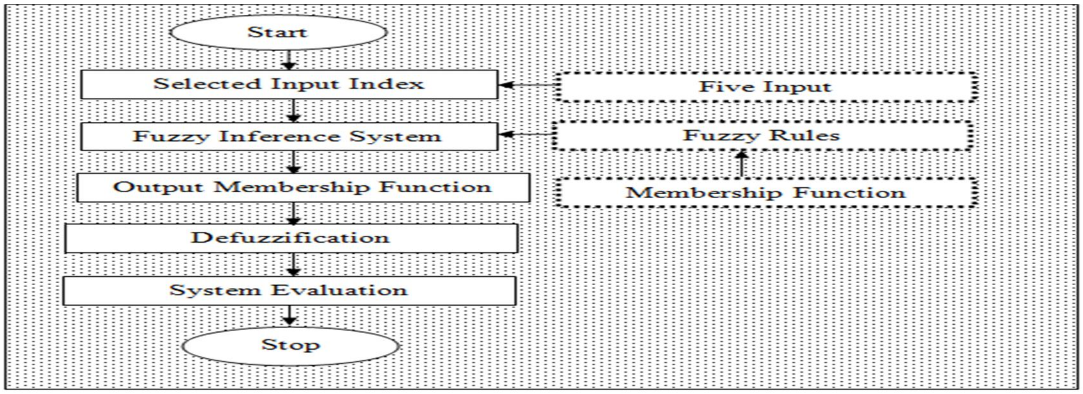

Figure 2: Design Methodology

The fuzzy rules will also depend on the available degree of membership function in order to enable certain estimation of River water. The developed system will be evaluated based on the available result of designed and ideal output.

B. Selection of Input Index

Five Parameter proposed as input index-based determination of river water quality the available ranges from each of the five parameters serves as an input to MATLAB Fuzzy Logic system in Figure 3.

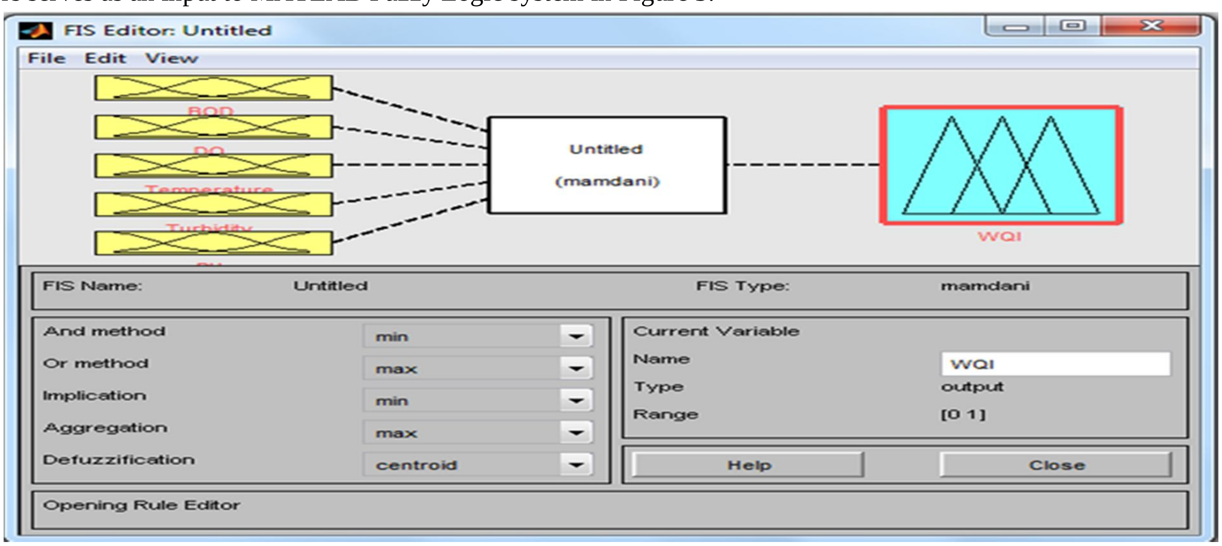

Figure 3: Five Input Indices

C. Development of Input Membership Function

The membership function base on available five inputs were developed using good, average and bad degree of membership. One of the reasons for using the three degree of membership is based on the fact that some portions in River can experience good, average and bad qualities of water due to some certain activities taking place in various portions un the river.

D. Biochemical Oxygen Demand Membership Function

A membership function of ''Biochemical Oxygen Demand'' is developed with maximum and minimum range of values based on experimental practical that took place in laboratory the method consists of putting a sample in a full, airtight bottle and incubating the bottle under specified condition for a specified period of time Dissolved Oxygen (DO) is measured initially and after incubation. The BOD is computed difference between the initial and final DO is calculated.

Final DO was determined after incubation of sample in BOD bottles in a dark cupboard for 5days.

Calculation

$$BOD(mg/l) = \frac{D_1 - D_2}{P} \qquad (v)$$

Where

D_1 =of initial sample immediately after preparation (mg/l)

D_2 =DO of diluted sample after 5 days incubation at 20℃,(mg/l)

P =Volume fraction of sample used

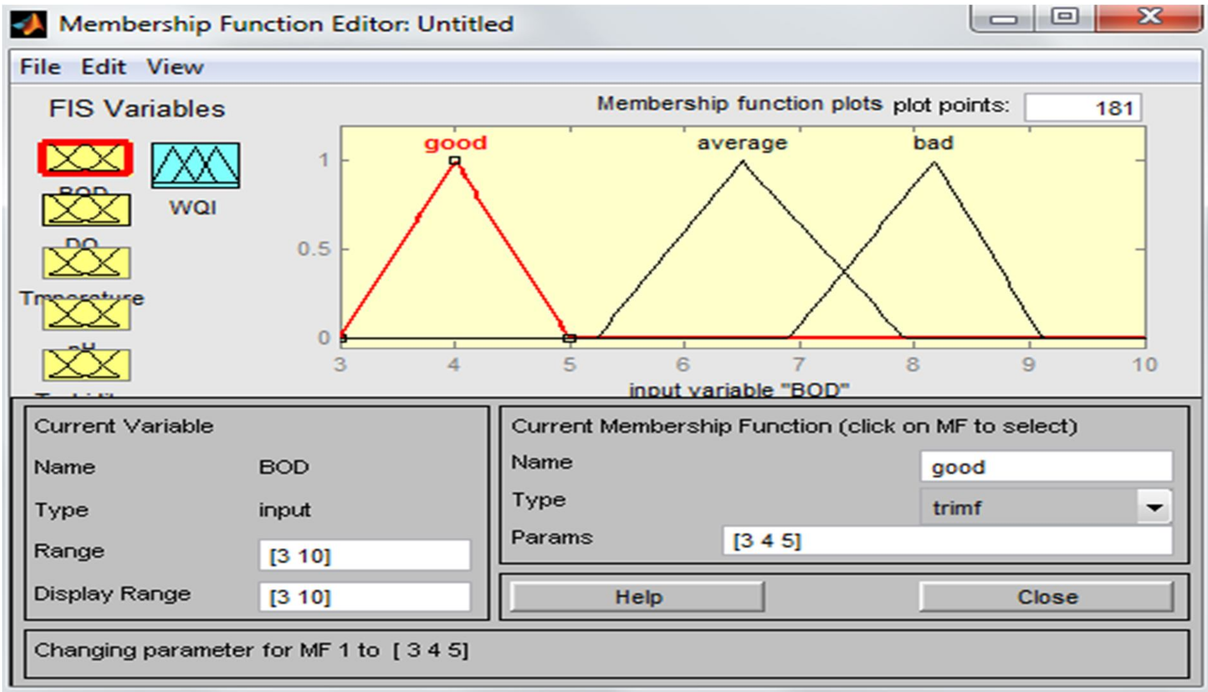

Figure 4: Biological Oxygen Demand Membership Function

E. Dissolve Oxygen Membership Function

In this study, 300ml BOD bottles were filled with the samples respectively, 2ml of manganese sulphate and 2ml of alkaline iodide-azide solution added by inserting pipette just below the surface of the liquid. Two hundred and one millilitre of the sample was then measured into a clean 250ml conical flask and titrated against sodium sulphate solution ($Na_2SO_3H_2O$) using starch indicator until the solution turned colourless.

Calculation

$$DO(mg/L) = \frac{16000 \times M \times V}{{V_2}/{V_1}\,(V_1 - 2)} \qquad (vi)$$

Where

V =Molarity of thiosulphate used for titration

V_(1 =Volume of bottle with stopper)

V_(2 =) Volume of aliquoted taken for titration

Table 2: Dissolve Oxygen Membership Function

Membership		degree	Range
Good	25.5	28.5	39.5
Average	12.5	23.5	25.5
Bad	3.4	7.5	12 .5

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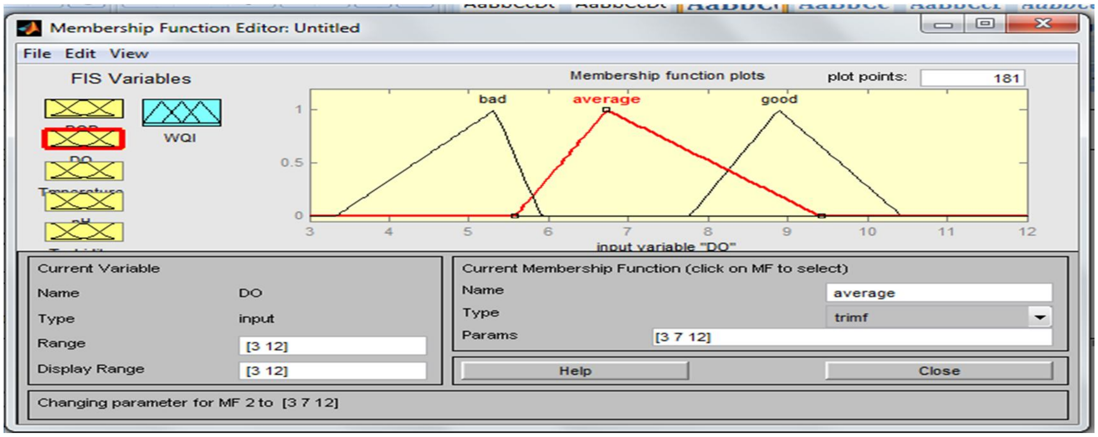

Figure 5: Dissolve Oxygen Membership Function

F. Potential Hydrogen (pH) Membership Function

The pH metre was calibrated using buffer 4 (KHP) and buffer 7 (phosphate buffer) before use. The metre is then immersed into a fresh portion of the sample and the pH read.

pH meter with glass electrodes.

Table 3: pH Value

Membership degree range		
Good	6.7	8.07
Average	7.0	7.08
Bad	6.0	6.07

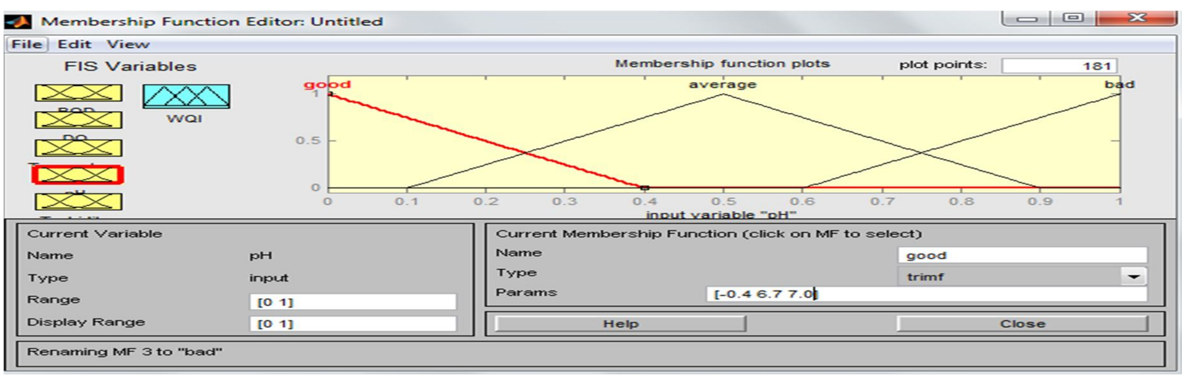

Figure 6: Potential Hydrogen Membership Function

G. Temperature Membership Function

Temperature is developed by A membership function of ‘‘Temperature’’ is developed with maximum and minimum range of values based on experimental practical that took place in study site which at river water by the use of temperature apparatus Digital water temperature thermometer thermometers.

Table 4: Temperature

Membership degree range		
Good	27.34	27.4
Average	27.60	28.15
Bad	25.0	25.5

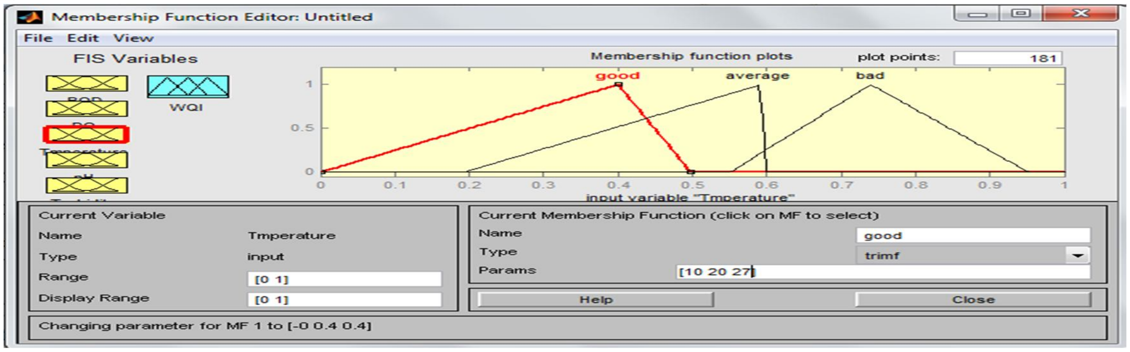

Figure 7: Temperature Membership Function

H. Turbidity Membership Function

Turbidity is developed in the water to determine the transparency of the water in river by using the turbidity apparatus which is known as turbidimeter in the river.

Table 5: Turbidity Membership Function

Membership degree range		
Good	18	35
Average	40	51
Bad	55	90

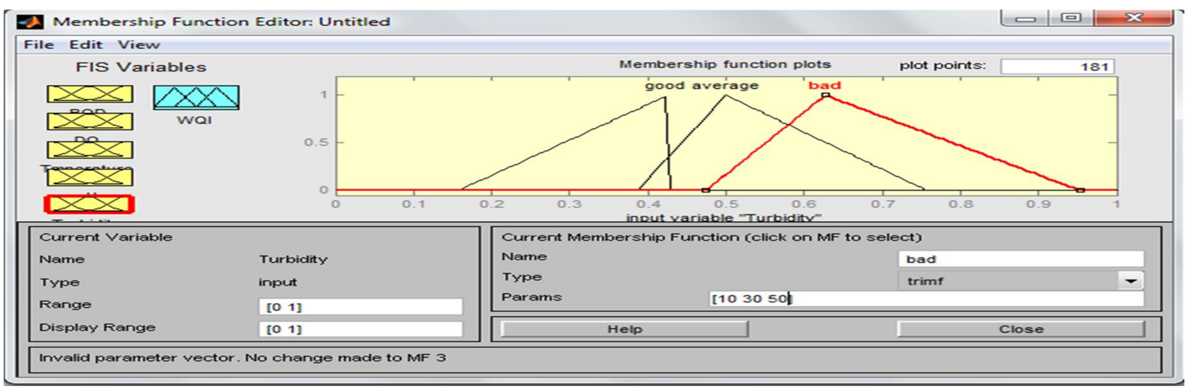

Figure 8: Turbidity Membership Function

I. Development of Fuzzy Rules

The algorithm is developed using rule editor in Figure 8 from the five available degrees of membership function of (3) × (3) × (3) × (3) × (3) = 243.

IV. RESULTS AND DISCUSSION

This section presents the discussion of results obtained from Fuzzy Logic system using rule viewer and surface plot. The performance of the developed fuzzy rules is tested in the rule viewer with different antecedents at the five -input levels and the consequence is obtained at the output level. Each row in the rule viewer represents certain fuzzy rules while each column represents the input that interrelate with the rules to provide a logical proof for a particular choice of outcome. The surface plot provides relationship between single and multiple inputs in respect to a given output.

The input and output relationship of the rule viewer at Water Quality Index is given in Figure 9. Five inputs were used to generate a condition for Water Quality Index which, Rule 1 is activated, determined that:

R1: IF (BOD is GOOD), (DO is GOOD), (TEMPERATURE is GOOD), (pH is GOOD) and (TURBIDITY IS GOOD) THEN (WQI is GOOD)

The output indication is shown in Figure 9.

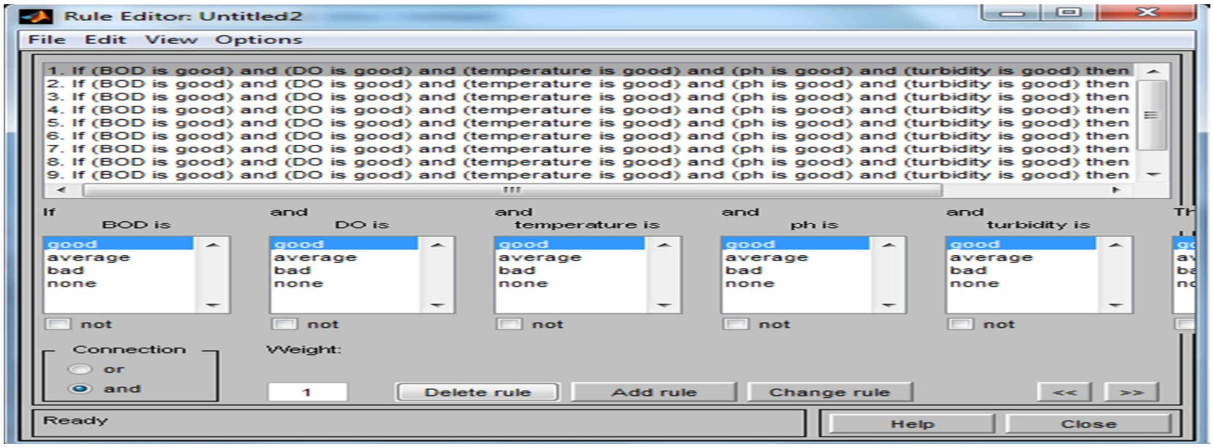

Figure 9: Rule Editor of Inputs

After the inputs of rules in rule editor by the using of AND gate to generate the output in the rule viewer by plotting the graph for the five input and also the output in figure 4.2 to determine and also to predict the quality of the water base on the range value inputted in Membership function editor.

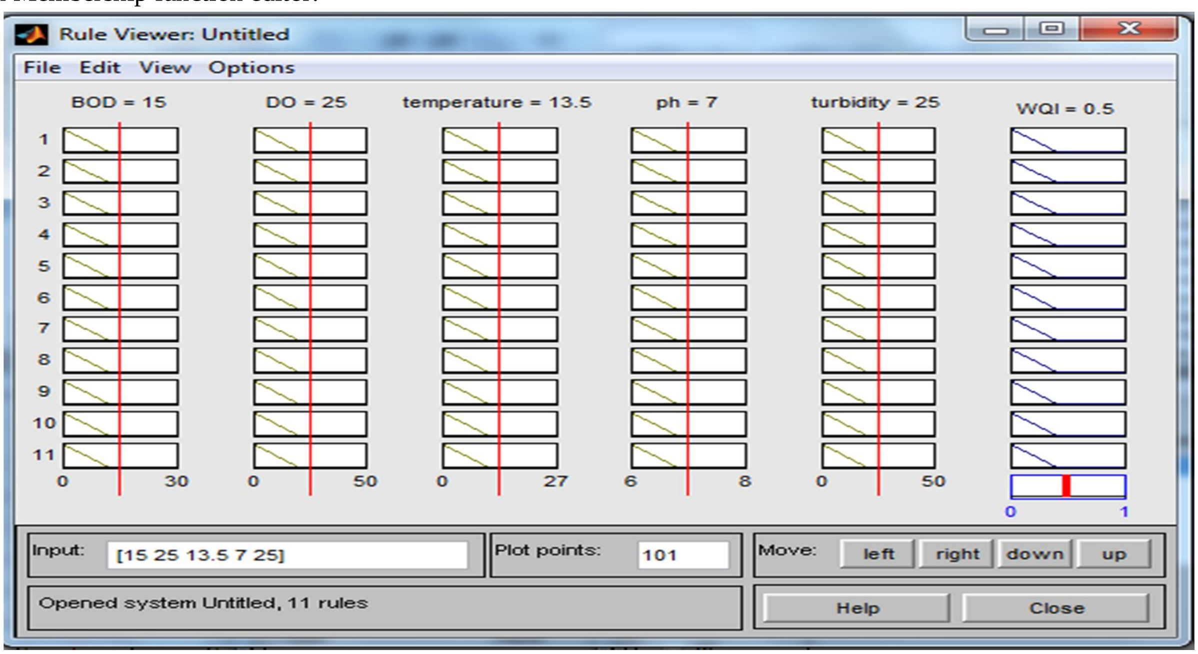

Figure 10: Rule Viewers of Inputs and Outpu

A. Performance Evaluation

Performance evaluation determined whether the resulting meet the standards of acceptability.

Table 6. Result of Characterization of Yaba River in Katcha Town

All results are express in mg/L except for pH values and temperature was measured in°C.

Samples	W_{11}	W_{12}	W_{13}	W_{14}	W_{21}	W_{22}	W_{23}	W_{24}
pH	7.08	6.90	6.79	7.43	6.94	6.85	6.8	8.87
Temperature	27.60	27.40	28.15	27.40	27.35	27.40	28.15	27.15
DO	3.4	7.0	12.8	39.4	23.0	25.5	28.5	36.2
BOD	3.6	3.5	3.5	5.0	3.8	3.4	3.6	3.1
Turbidity	40	51	136	55	18	53	99	38

B. Surface Viewer BOD and DO Input

The relationship between Biological Oxygen Demand and Dissolved Oxygen determined is given in Figure 11. The output ranges from 0 to 0.5 for which the Biological Oxygen Demand ranges from 0 to 15. The surface viewer shows, the rate of DO range from 0 to 25 is good.

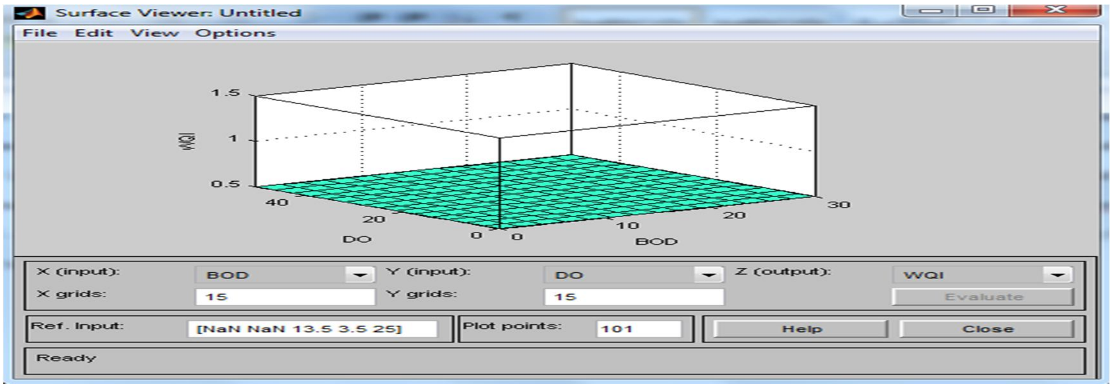

Figure 11: BOD and DO Relationship

C. Surface Viewer of Turbidity and Temperature

In Figure 12, the relationship between the Temperature and Turbidity is given within the output range of 0.5 and an input range of turbidity from 0 to 25. The level of Turbidity rate is good and level of Temperature from the range of 13.5 to 27.40 which provide determination for good rate of river water.

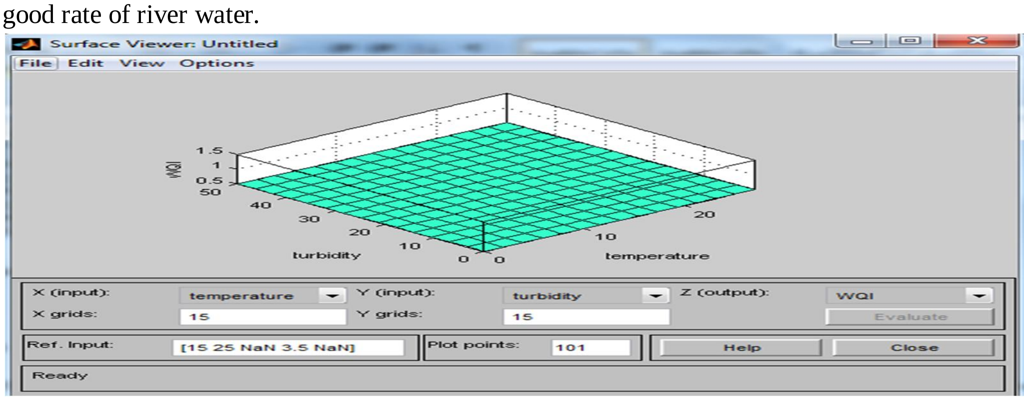

Figure 12: Turbidity and Temperature Relationship

D. Surface Viewer of Temperature and Potential Hydrogen (pH)

In Figure 13, the relationship between the Potential Hydrogen (pH) and Turbidity is given within the output range of 0.5 and an input range of turbidity from 0 to 25. The level of Turbidity rate is good and level of pH from the range of 6.5 to 7.3 which provide determination for average rate of river water.

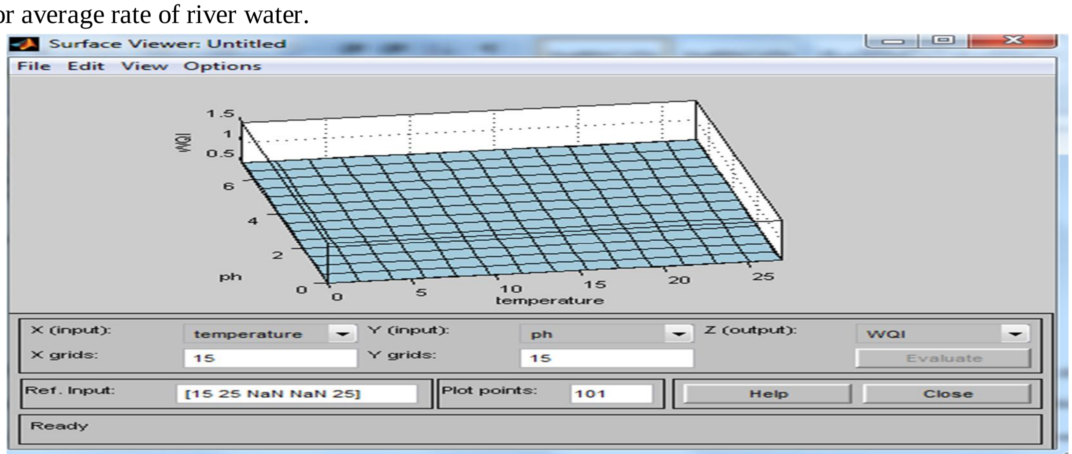

Figure 14: Temperature and pH Relationship

E. Summary

Water quality is essential to our wellbeing therefore, support life for both human and animal on earth. Water quality is defined in terms of the chemical, physical and biological contents of water, water quality guidelines provide basic scientific information about water quality parameters and ecological relevant to protect specific water use. Important physical and chemical parameters of water are turbidity, temperature and $_p$h.

Temperature is the most important environmental variable. Water temperature directly or indirectly influences many biotic and abiotic components of aquatic animals. The Fuzzy logic is use to assess water quality by developing a water quality index based on fuzzy reasoning Fuzzy logic provides a framework to model uncertainty, the human way of thinking, perception, and act.

V. CONCLUSION

Base on the results obtained, the pH and temperature are within the minimum permissible limit by World Health Organization (WHO) and Federal Environmental Protection Agency (FEPA). Dissolve oxygen was found to be above maximum permissible limit by WHO and FEPA water standard though good for high activities of living organism in the river. Biochemical oxygen Demand BOD are within the minimum permissible limit, also the result shows that the turbidity are above maximum permissible limit as set by WHO and FEPA standard. These make river water unfit for consumption without treatment.

In conclusion, Yaba River can best be describe to be unfit for human consumption without any form of treatment, however, it may be good for agricultural activities such as irrigation and some domestics activities with reasonable caution.

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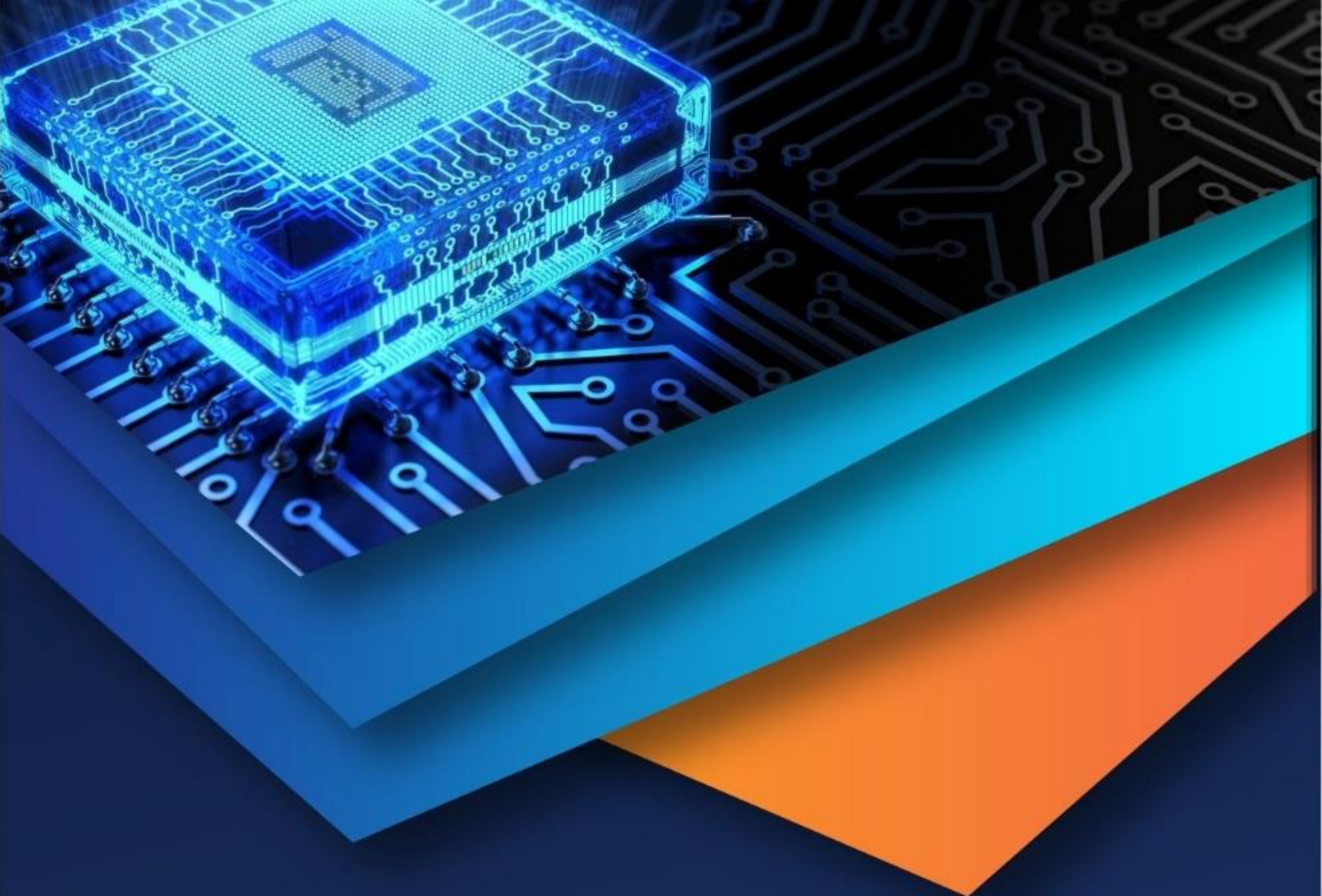

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