Fuzzy Logic Based Water Quality Analyzing System

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Abstract: Water is one of the most important natural resources on the earth. Clean potable water is the right of each human being. As contaminated water can cause many diseases, it is necessary to monitor the quality of the drinking water on the regular basis. Therefore, this paper suggests the measurement of important water quality parameters like turbidity, pH and water color using multi-sensor technique. These measured quality parameters are analyzed and compared with the standard values provided by Bureau of Indian Standards(BIS) using MATLAB, to display the water quality results. As water quality is subjective by nature, proposed technique makes use of fuzzy logic model to overcome any data uncertainties and hence to obtain the more reliable and accurate water quality results. Proposed technique is intended to provide the accurate water quality results in very less amount of time compared to the conventional complexometric and colorimetric titration methods.

***IndexTerms* – Water Quality, Fuzzy Logic, MATLAB, Sensors**

I. INTRODUCTION

Water is one of the most important and vital substance on the planet. Water is essential for the survival of every living organisms on the earth. 70% of the human body is made up of water and every individual on earth requires at least 20 to 50 liters of clean water per day for the survival. But due to the increased population, industrialization and urbanization, availability of the safe water is becoming a major issue around the globe. Degraded water can cause adverse effects on human health, aquatic creatures and surrounding ecosystem. Therefore, regular water quality testing and monitoring of water bodies is essential, to prevent our water resources from the pollution.

Water quality parameters can be physical, chemical or biological; Physical parameters include color, temperature and turbidity. Chemical properties include dissolved oxygen and pH etc., whereas biological properties include E-coli bacteria, algae or phytoplankton. These properties are expected to comply the standard reference values provided by World Health Organization (WHO) and BIS.

In the Proposed technique, water quality indicating parameters measured are:

- pH
- Turbidity
- Color

Potential of Hydrogen (pH) is the measure of hydrogen ions concentration in the given sample. Standard pH range will be from 0- 14. pH test determines the acidic or alkalinity of the water. Water with pH of 7 is considered to be normal or neutral. Whereas, above 7 is considered to be caustic or basic and below 7 is considered to be acidic in nature. pH range of 6.5 to 8.5 is acceptable for the drinking water. Acidic water will give metallic taste to the water and causes corrosion to the pipes and fittings. Caustic water will be having soda like taste to the water and causes deposits on the containers and they causes some adverse health effects.

Suspended particles and solids in the water makes the water to lose its transparency and makes the water to appear cloudy and murkier. Water turbidity is a measure of clarity of the water or the measurement of degree at which transparency of the water will be lost. As amount of scattered light in water varies directly with the suspended particles, turbidity is measured by computing the intensity of the scattered light in the water. Nephelometric turbidity units (NTU) is the standard unit for measuring the water turbidity. Waste water discharge, erosion, sediments, phytoplankton and growth of algae etc. are the main cause for the water turbidity. Turbidity of the drinking water should be below 5NTU, up to 10NTU is also acceptable as per the BIS provided standards.

Water at its purest form is expected to be colorless. But due to the presence of impurities or ambient conditions, water color varies from light blue, light green to yellow. Discoloration in the water is typically measured using Hazen units(HU). For potable water color should be below 25HU. Color in the water doesn’t mean, water is contaminated, but color in water makes the water to lose its acceptability.

Proposed technique tries to measure the above-mentioned quality indicating parameters using different analog sensors; Arduino UNO is used for the interfacing of sensors with the computer. These sensors measured values are calibrated and analyzed using MATLAB. Using MATLAB fuzzy tool kit, water quality parameters are compared with the reference values provided by BIS. In this paper, fuzzy logic module is intended to provide the more reliable water quality results by handling any data uncertainty issues.

II. LITERATURE SURVEY

Eric et al[1] explains about determining the different physical and chemical characteristics of the ocean water with the help of multi-sensor technique. These sensors are capable of adaptive observations. This paper also suggests about sensor-fusion techniques for joining different sensors to get the unified results. They are using the spectrometric color sensors, which has high sensitivity for getting water quality results.

Dissanayake et al[2] developed a low-cost water quality measurement technique, which measures hardness, fluoride and conductivity and salinity of the water using sensors and colorimetric titration methods. This method makes use of microcontrollers for displaying the water quality results. This technique developed water quality measuring instrument at the very affordable cost. Also makes use of GSM module, for sending results remotely.

Jyotirmoy et al[3] describes about bio, optical and electro-mechanical based sensors for detecting various water quality indicating parameters. E-coli, bio chemical oxygen demand and dissolved oxygen (DO) of water is measured with the help of optical and bio-sensors. These sensors are reliable and response time is very less compared to the traditional water quality monitoring techniques used so far.

Muhammad Imran Khan et al[4] proposes an electro-mechanical instrument for the detection of pH of the given sample. Proposed technique compares different pH measuring techniques for different samples.

Carbajal-Hernández et al[5] explains about implementation of artificial intelligence approach for air quality detection. Proposed technique measures air quality parameters and compares it with the standard reference values to display the air quality results. Fuzzy-auto regressive model has been used for categorizing and displaying air quality result of the Mexico City. Fuzzy-auto regressive models correlate data automatically and its output is more reliable due to the superior fuzzy inference technique compared to the conventional fuzzy inference.

Babaei Semiromi et al[6] conducted a case study to obtain the quality results for the Karoon river, Iran. Non-linearity and uncertainties problems faced by the other water quality measuring techniques are handled by usage of fuzzy logic model in this case study. This paper suggests the measurement of total dissolved solids (TDS), temperature, nitrate and dissolved oxygen of the river and compares with the standard reference values.

Nilesh Dashore et al[7] describes about a fuzzy based technique for pollutants present in the air around the globe. Pollutants such as suspended particles, carbon monoxide and Sulphur dioxide are categorized, and air quality results are displayed accordingly. For obtaining accurate air quality results, fuzzy model has been implemented.

Huaiyu et al[8] explains about data fusion technique for combining and inferring of the different sensor measured values. This paper also makes use of an optimal way of collection, transmission, compression and analysis of data obtained from multi-sensor technique in an effective way. Data fusion provides integration of various data from various sources to obtain unified results, which is more consistent, reliable, precise and correct.

Ashish Pandharipande et al[9] describes about determination of object's color, by using light emitting Diode (LED) techniques. Wavelength selection of the LED source is the base for color detection. Setup makes use of LED arrays and lamps for the detection of object color.

Weidong Gong et al[10], has explained about detection of nitrite amount in the seawater sample; Optical detection methodology has been implemented for the nitrite detection. This method mainly uses double beam photo spectrometer, LEDs and photo detectors nitrite detection. Output which is directly proportional to the absorbance can be produced by using an amplifier circuit.

All the above described papers make use of different techniques for monitoring environmental factors. They use various algorithms for measurement and data analysis. From all the above papers, it was evident that the all the environmental factors such as water, air and pollutant presence etc. are highly indeterminate and subjective of the nature and the surrounding system. To overcome these uncertainties, fuzzy logic model is the best suitable technique.

III. **FUZZY LOGIC**

Something which is vague in nature often referred as 'fuzzy'. Fuzzy logic computation considers degrees of truth, rather than conventional 'True' or 'False' logics. It is a reasoning strategy, that resembles human reasoning. It is apparently many valued logic, in which truth values can be in the range of anything between 0 and 1. Fuzzy logic definitely doesn't provide accurate reasoning, but it does provide acceptable reasoning. Due to this fuzzy logic has been used in numerous fields and applications. It is used in aerospace engineering fields, automobiles control units, various process and chemical industries and in various control system applications.

A fuzzy logic algorithm has following major steps:

- Process of Initialization: Where linguistic terms, membership functions and fuzzy rules are initialized and constructed as per the requirement.
- Crisp inputs (System inputs) are converted as fuzzy sets, with the help of membership functions, this step is generally known as fuzzification.
- Constructed fuzzy rules are analyzed.
- Combining the results of each fuzzy rule
- Conversion of the output data into non-fuzzy or crisp values, known as defuzzification.

Fuzzy logic mainly consists of 4 main parts and fuzzy architecture diagram is shown in the figure 1.

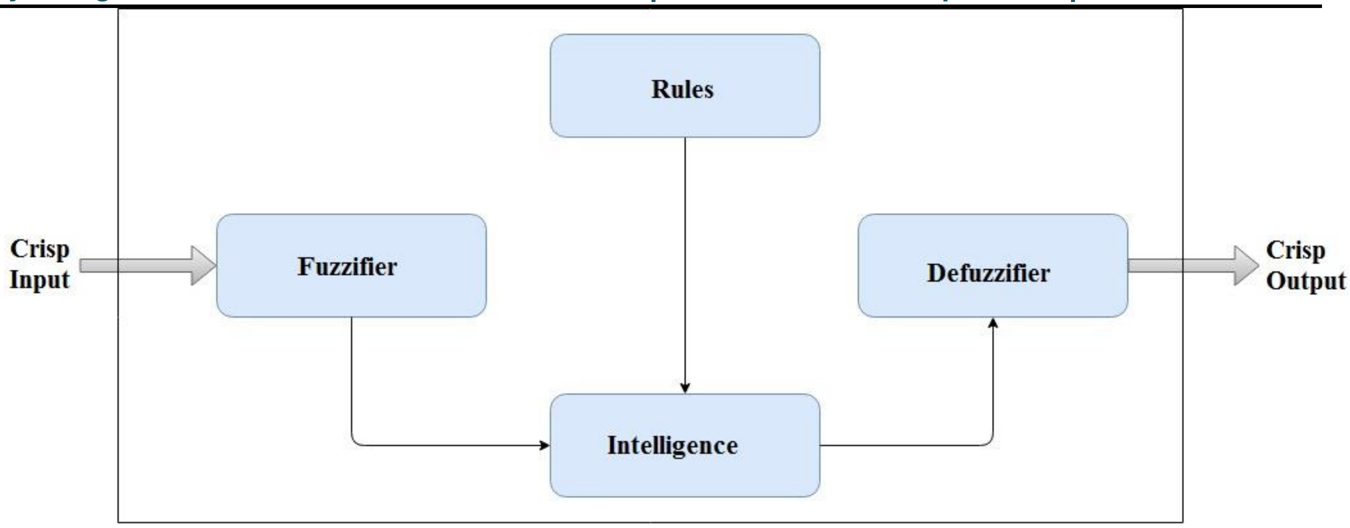


Figure 1: Fuzzy Logic Architecture

Where fuzzification represents the first step of fuzzy computation, where crisp inputs or sensor measured values are converted as fuzzy sets. Expert provided IF-THEN rules are stored in in the 'Rule' module, which is based on the linguistic information. 'Intelligence' or inference engine selects the suitable rules according to the input variables and IF-THEN rules to provide human like reasoning and to obtain the best possible results. Defuzzification module transforms output obtained in terms of fuzzy set as crisp output values. Membership Functions(MF) forms the base block of the fuzzy logic; Linguistic variables along with graphical fuzzy set representation is known as membership functions. In fuzzy logic, MFs represents degree of truth. Membership functions can be depicted using various types of graphs and shapes, such as triangular, trapezoidal, singleton, piecewise linear and gaussian MF etc.

IV. RESEARCH METHODOLOGY

This section describes about the outline of the proposed technique and the tasks carried out to implement this project, which can be seen here below.

4.1Block Diagram

The experimental setup designed for the proposed water quality measurement technique consists of pH sensor, color sensor and turbidity sensor, Arduino Uno board and PC (MATLAB). pH, turbidity and color values measured from the sensors are sent to PC, where MATLAB is installed. Arduino Uno is used for interfacing of sensor with the PC. MATLAB is used to compare the measured values with the reference values and to display the water quality results. Accurate results and acceptable reasoning is obtained by the use of fuzzy logic model. Block diagram of the proposed, water quality measurement system is shown in the figure 2.

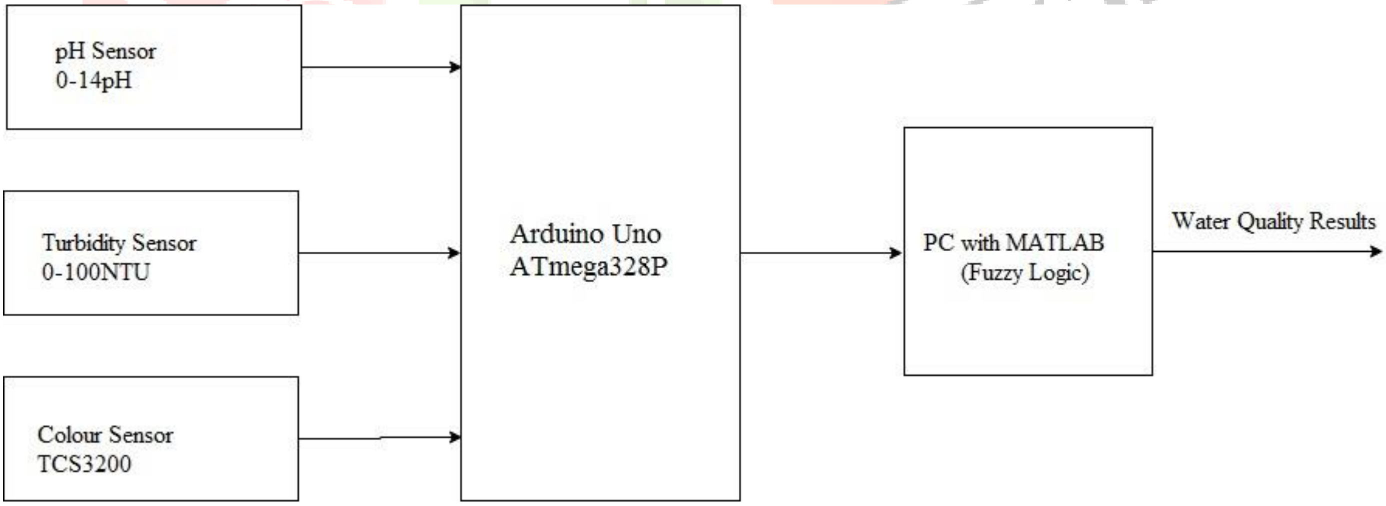


Figure 2: Block Diagram of the Proposed Technique

4.2Sensor Interface and Data Acquisition

pH and turbidity probes are immersed in the water sample and their other end is connected with electronic conditioning board. Electronic signal conditioning boards help to filter noise and amplify the signals and to obtain more legible sensor outputs. Supply and grounding connections are made as per the sensor specification. Output of the pH and turbidity signal conditioning circuit board will be connected to the A0 and A1 terminal of the Arduino board respectively. Color sensor is kept in such a way to, face the water color from the transparent container. Color sensor terminals Arduino digital pins as per the specifications and output of the sensor is connected to the pin 8 (digital pin) of the Arduino Uno board and 5V supply is given to trigger the sensor.

Collection of data from sensors is frequently referred as data acquisition. Generally, a data acquisition module is made up of sensors, software and other hardware required for the data collection. All the three measured values i.e. pH, turbidity and color are sent to PC via Arduino interface. Arduino board is connected to PC using a USB connection cord, so that measured data will be sent to PC(MATLAB) for analyzing the water quality. These sensors are calibrated using the suitable calibration techniques; code for reading the sensor output, calibration and for data transmission is written in Arduino IDE (Integrated Development Environment). Serial communication protocols are used for data transmission from Arduino Uno board to PC.

4.3 Experimental Setup

Experimental setup designed for measuring the water quality can be seen in the below figure 3. All the mentioned sensors are connected as mentioned in the previous steps. Arduino Uno is connected to the USB port of the PC, to transfer the sensor measured values.

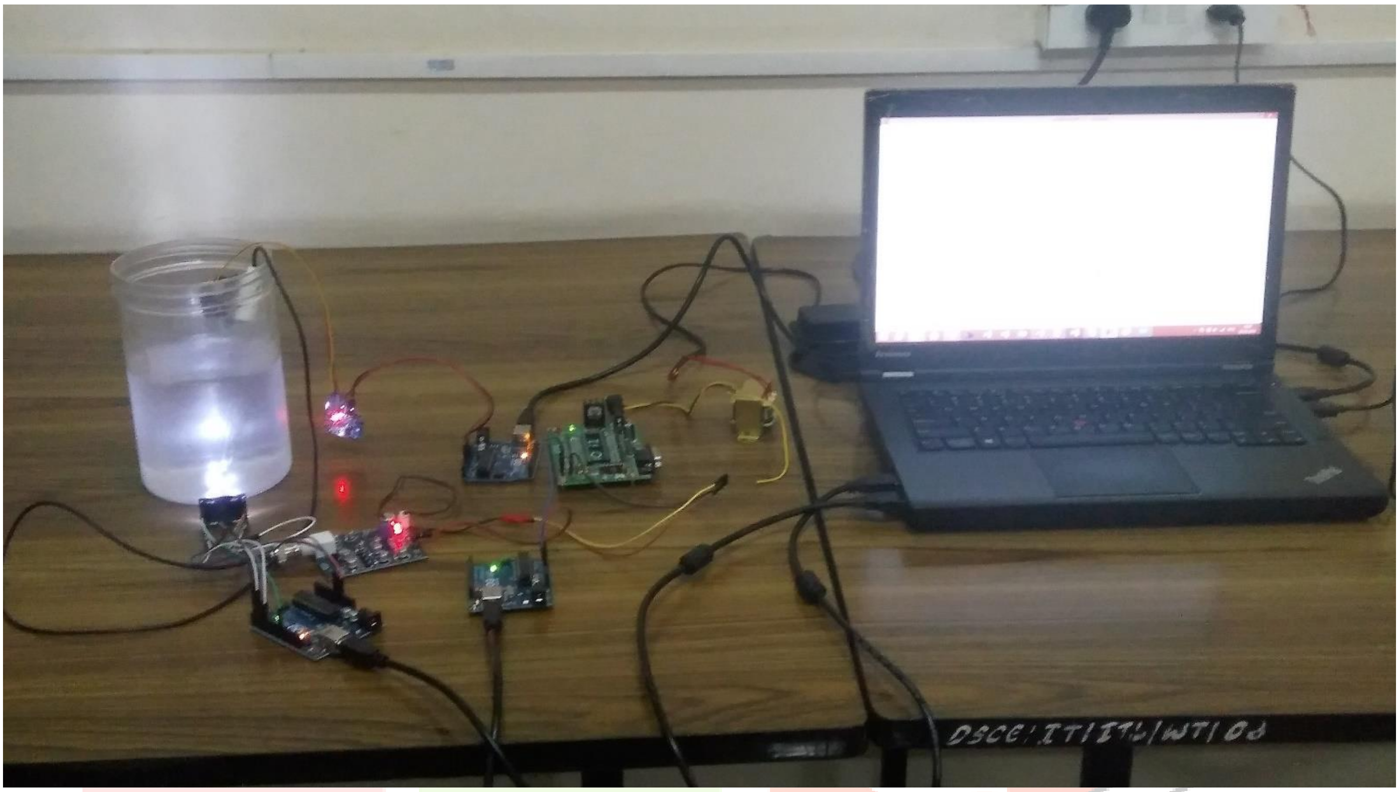


Figure 3: Experimental Setup of Water Quality Measurement

4.4 Computation by Fuzzy Logic

Water quality measurement technique involves below mentioned steps for fuzzy logic and simulation module creation:

- Creation of 3 input blocks for three sensors in the MATLAB fuzzy logic toolkit.
- Sugeno fuzzy inference is used.
- Crisp values converted as fuzzy sets, as per the requirement.
- Fuzzy rules for the system are designed with the help of fuzzy 'rulebase editor' provided by MATLAB fuzzy toolbox.
- Created fuzzy module is referred inside Simulink using 'Fuzzy Controller' block.
- Weighted average defuzzification method is used to obtain the water quality results.

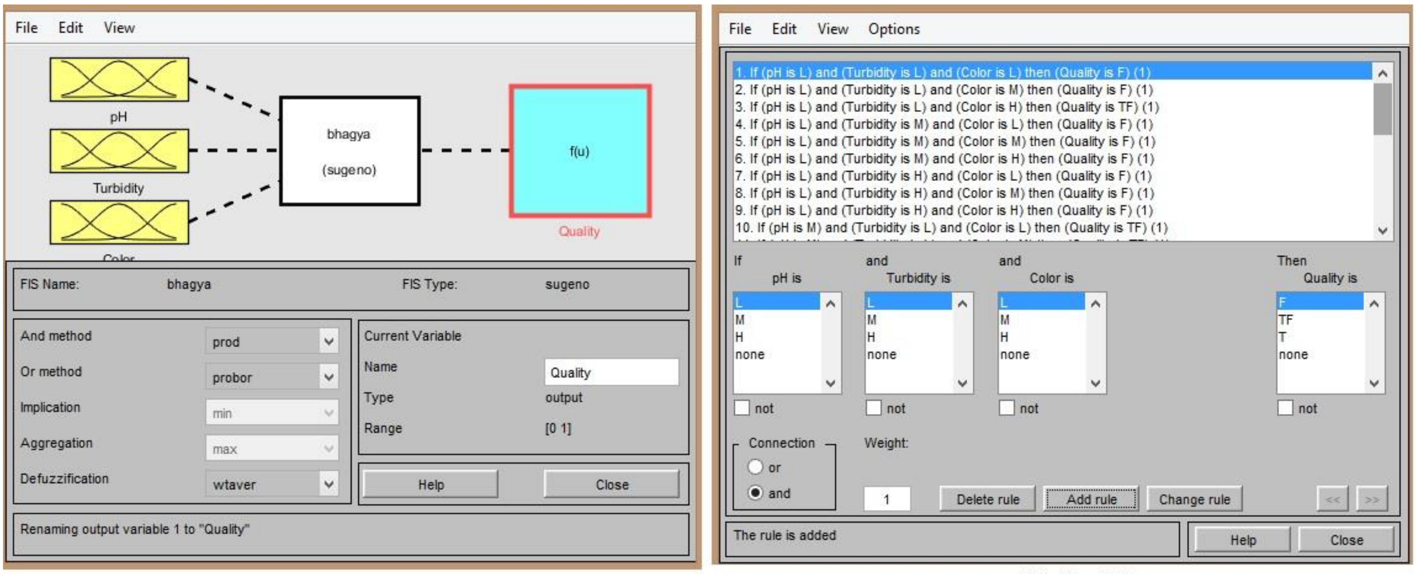
In this project, triangular membership functions plots are used, as it is easy for the computations compared to other available membership functions plots. Three input variables, linguistic terms and their ranges are mentioned here below table 1. In this proposed technique three linguistic variables are considered for the inputs turbidity and water color, i.e. Low(L), Medium (M) and High (H); whereas, five linguistic terms are used for pH, i.e. Very Low (VL), Low (L), Medium (M), High (H) and Very High (VH) and their ranges are considered as shown in the below table. Total of 45 fuzzy rules has been written for the proposed technique using MATLAB, fuzzy rule base editor.

Table 1: Inputs and Linguistic Term Ranges

Linguistic Variables	pH Range	Turbidity Range (NTU)	Color
VL (Very Low)	-inf to 6.6	NA	NA
L(Low)	6.5 to 7	0 to 7	-inf to 226
M(Medium)	6.8 to 8.3	6 to 10	225 to 230
H(High)	8 to 8.5	9.9 to inf	228-255
VH (Very High)	8.6 to inf	NA	NA

Three output variables True (T), False (F) and TF (True or False) are designed. Where 'True (1)' indicates water, quality is good and can be used for drinking; False (0) indicates water cannot be used for drinking. True or false (0.5) indicates anyone parameter is not in range and not safe for drinking purpose. Anything below '1' is considered as not safe for drinking.

Designed fuzzy logic block and fuzzy rules using MATLAB fuzzy toolkit for the proposed system is shown in the figure 4.



Fuzzy Logic Block Designed in MATLAB Rule Base Editor

Figure 4: Fuzzy Logic Design and Designed Fuzzy Rules

4.5 Standard Reference Values Provided by BIS

Drinking water needs to comply the standard reference values provided by the World Health Organization (WHO) and Bureau of Indian Standards (BIS). These standard values are provided for promoting the good human health and eco systems. Proposed water quality measurement technique compares the obtained output with the BIS provided standard water quality reference values, to display the water quality results. BIS provided standard reference values for the parameters pH, turbidity and water color is shown in the table 2.

Table 2: BIS Provided Standard Reference Values

Parameter	Permissible Range for Potable Water	Risks or Effects
Turbidity	0-10NTUs	Water appears cloudy and becomes unsuitable for drinking.
pH	6.5-8.5	Low pH value than 6.5 results in corrosion, metallic taste of the water High pH value than 8.5 results in bitter/soda taste and deposits
Color	Hazen Units (0-25) or RGB nearest to Clear, light blue	Visible tint, acceptance

V. RESULTS AND DISCUSSION

This section explains about the obtained water quality results for the different water samples and bar chart representation for the pH and turbidity.

5.1 Water Quality Results for Different Samples

Water quality results obtained from the proposed technique for four different samples are shown in the below table 3:

Table 3: Output Obtained for different Samples

Samples	pH Output	Turbidity	Colour	Water Quality Result
Sample 1	7.947	3.28	255	1(Good)
Sample 2	5.59	81	210	0(Not Drinkable)
Sample 3	9.84	12	224	0(Not Drinkable)
Sample 4	7.2	1.4	255	1(Good)

pH and turbidity values obtained for the different water samples, along with BIS provided reference values for drinking water is shown is represented using the bar charts as shown in the figure 5.

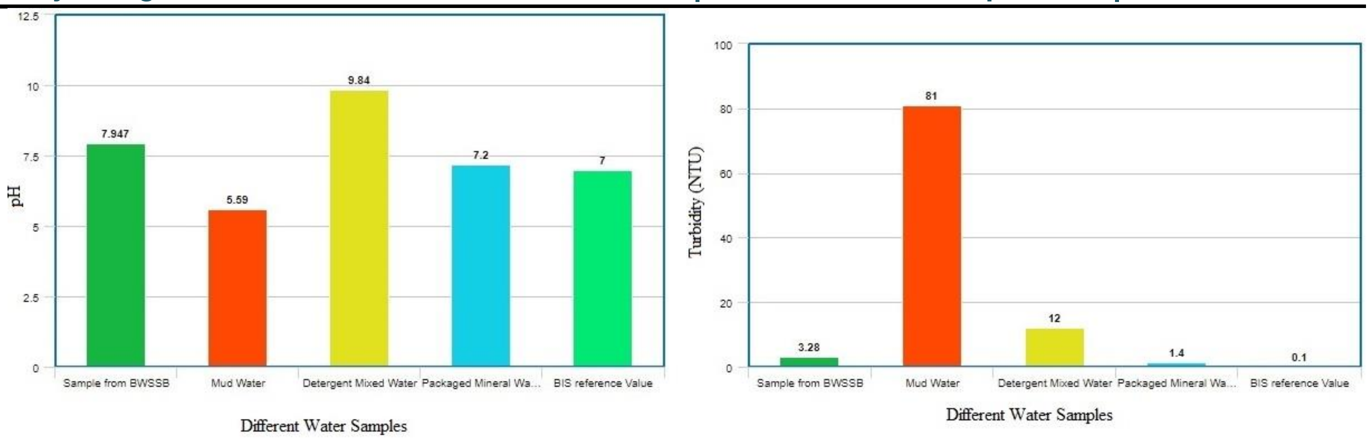


Figure 5: Bar Chart Representing pH and Turbidity Values for Different Water Samples

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