Real Time Water Quality Monitoring and Management System

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Abstract - *Water pollution has been an increasing problem over the decade. The conventional method of testing water quality is to assemble samples of water physically and send them to the lab to test and analyze. This paper proposes a Real Time Water Quality Monitoring & Management system; which will allow water quality monitoring at household levels as well as help in limiting the use of this natural resource. The objective of the proposed water quality monitoring system based on the technology of internet of things (IoT), is to observe the nature and quality of the tap water i.e., how the pH content & total dissolved solids (TDS) content varies and to provide a user-friendly interface with infographics and meters to illustrate the quality factors.*

For development of this system, the developers will be using an Uno R3 ATmega328p Arduino Development Board and sensors for finding pH value, TDS content & flow rate of the tap water and a GSM module for message technique.

***Key Words*: Internet of Things (IoT), Arduino, Water Quality Monitoring, Water Management, Smart System, Smart Buildings**

1.INTRODUCTION

Waterborne diseases are uncontrolled in India because of undeniable degrees of biological contamination of water. Yearly about 37.7 million Indians are influenced by waterborne infections, 1.5 million children lose their lives to diarrhoea and 73 million working days are lost prompting an economic burden of estimated $600 million every year.[1] A study proves that the high concentration of nitrate, chloride and faecal coliforms in its water where river Ganga flows through the city of Varanasi is found to have a direct link to the prevalence of enteric diseases in the city. Tap water & water sourced from ground, via borewell, contamination due to fluoride, arsenic, iron, manganese, uranium and radon is high in selected states in India. Another study reveals that Drinking water with excessive TDS can be harmful and might lead to problems like causing kidney stone (excess calcium).

Knowingly, unknowingly, people also waste water every day. In urban cities of India, people use about 27% of water for bathing and toilet use. On an average, it is estimated that one person wastes about 0-45 litres of water per day. To understand it better, it is 30% of the water requirement per person per day. 125 million litres of water wasted daily only in these cities.

The remaining part of the paper is structured as follows: Section 2 describes the related work. The selection of parameters to be observed are discussed in Section 3. The design and specifications are mentioned in Section 4, while Section 5 describes the methodology of the system. Section 6 writes the experimentation and Section 7 about the future scope presented by the authors, followed by conclusion.

2. LITERATURE REVIEW

Before proceeding with research in any particular field, it is imperative to learn the basics of the field and then advance in it. It is equally important to understand the current scenario in the particular field and propose a future of the same. The primary focus of this review is to examine the available technologies and propose advancements in water quality monitoring and management systems.

Michal Lom et al. describes the concept of the Smart City Initiative and its conjunction with Industry 4.0. [2] The term smart city has been a phenomenon of the last few years, which has arched particularly since 2008 when the world was hit by the financial crisis. The primary reason behind the rise of the Smart City Initiative is to make a sustainable and economical model for the community and uplift the quality of lifestyle of the residents and aim for their personal satisfaction. In the concept of Industry 4.0, Artificial Intelligence (AI) and the Internet of Things (IoT) will be utilized for the improvement of alleged smart devices and technology. Other significant aspects of the Industry 4.0 are Internet of Services (IoS), which incorporates particularly intelligent transport and logistics (smart mobility, smart logistics), as well as Internet of Energy (IoE), which determines how the natural resources are utilized in legitimate manner (power, water, oil, and so forth). IoT, IoS and IoE can be considered as an element that can make an association between the Smart City Initiative and Industry 4.0 – Industry 4.0 can be seen as a segment of smart cities.

Nikhil Kedia, in his research, features the entire water quality monitoring strategies, sensors, embedded design, and information dissipation procedure, role of government, network administration and the residents in ensuring systematic information dissipation. [3] It additionally shades light on the Sensor Cloud domain. While automatic water purification isn't feasible now, productive utilization of technology and economic practices can assist with further developing the water purification system and also raise awareness among people.

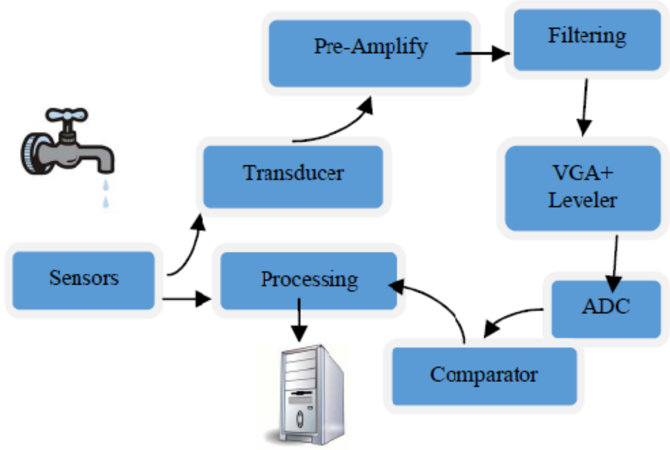

Fig -1: Embedded System Design
[Source: Water Quality Monitoring for Rural Areas-A Sensor Cloud Based Economical Project]

S. Geetha et al. describes smart solutions for water quality monitoring and a detailed overview of recent works in the particular field. [4] The author has also presented a simpler solution for in-pipe water quality monitoring based on IoT (Internet of Things) technology which can be used for monitoring the water quality in real time. The key parameters monitored in the proposed system are conductivity, turbidity, pH of the water and also water level.

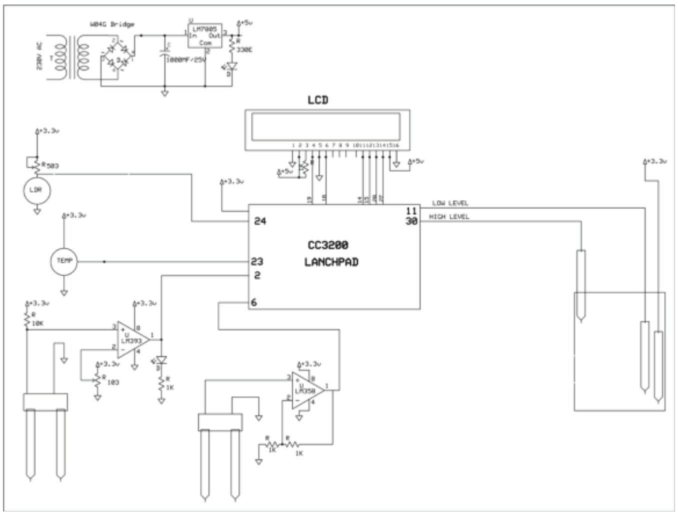

Fig -2: Circuit Diagram of the system proposed by S. Geetha & S. Gouthami

With the available technologies and future advancements, it can be proposed that a smart device which can not only monitor the water quality but will also help in management of this natural resource is in the near future, and a step towards a bigger goal of Smart City Initiative. Such systems will improve the lifestyle of the residents and can also be used for water tariff calculations and billing purposes based on consumption. The smart system will greatly help the residents in conserving the water resources.

3. SELECTION OF PARAMETERS

Water purification is the process of removal of undesirable chemicals, biological contaminants, suspended solids and gases from water. Direct consumption of tap water or debased water causes cholera, dysentery, typhoid, diarrhea and polio. The presence of pollutants in the water causes diseases like arsenicosis due to arsenic and fluorides components in the water. In most parts of India, tap water is not potable hence there is a need for smart water quality monitoring and purification systems. This system will notify the user regarding the purity of the water on some explicit water parameters.

As consistent with the 11th five-year plan document of India (2007-12), is can be estimated that approximately 2.17 lakh sections in the country are quality deprived with greater part affected with excess iron, accompanied by fluoride, salinity, nitrate and arsenic in that order. Further, approximately, 10 million cases of diarrhoea, more than 7.2 lakh typhoid cases and 1.5 lakh viral hepatitis cases are in light every year, a majority of which are contributed by means of unclean water supply and poor sanitation. [5]

As per the Bureau of Indian Standards, IS 10500 : 2012 Drinking Water - Specification (Second Revision) [5], acceptable and permissible limits have been specified based on WHO guidelines.

Table -1 Physical Parameters
[Source: Indian Standard Drinking Water - Specification]

Sr. No.	Characteristic	Requirement (Acceptable Limit)	Permissible Limit	Remarks
i.	Colour, Hazen units, Max	5	15	Extended to 15 only, if toxic substances are not suspected in absence of alternate sources.
ii.	Odour	Agreeable	Agreeable	a) Test cold and when heated. b) Test at several dilutions
iii.	pH Value	6.5 – 8.5	No relaxation	-
iv.	Turbidity, NTU, Max	1	5	-
v.	Total Dissolved Solids, mg/l	500	2000	-

As per the Background Document for development of WHO Guidelines for Drinking-water Quality entitled “pH in Drinking-water” [6], pH usually has no direct impact on water consumers, but it is one of the most important operational water-quality parameters. Careful attention to pH control is necessary at all stages of water treatment to ensure satisfactory water clarification and disinfection. The ideal pH will vary in various samples as per the synthesis of the water and the nature of the construction materials used in the distribution framework, but is often to be in the range 6.5–9.5.

Ideally, all samples taken from the distribution system, including consumers premises, are free from biological organisms due to Chlorination at water treatment plants.

As per the Background Document for development of WHO Guidelines for Drinking-water Quality entitled “Total dissolved solids in Drinking-water” [7], inverse relationships were reported between TDS concentrations in drinking water and the incidence of cancer, coronary heart disease, arteriosclerotic heart disease, and cardiovascular disease. Total mortality rates were reported to be inversely correlated with TDS levels in drinking-water. Water to be adequately purified enough for consumers must have TDS concentrations below 1000 mg/litre, although acceptability may vary according to conditions.

It was accounted for in a synopsis of a review in Australia that mortality from all categories of ischaemic coronary illness and acute myocardial infarction was increased in a community with undeniable degrees of dissolvable solids, calcium, magnesium, sulphate, chloride, fluoride, alkalinity, total hardness and pH when compared with one in which levels were lower.

Hence, based on the above facts, figures and research, the developers have reached to a conclusion of analyzing and monitoring the pH and the total dissolved solids (TDS) of tap water for this prototype.

4. DESIGN & SPECIFICATIONS

The first step in developing any technology is to state the requirements and then proceed with designing the same. The design should be based on the statement of needs and an innovative approach for a solution.

The water management unit will consist of a flow rate measuring sensor and an actuator to regulate the flow of water through the tap. The user has to set a value on the platform, and once the tap is ON it will only allow water to flow until the specified volume is reached. After the flow of water exceeds the specified value, the actuator stops the water flow and the tap runs dry. The user then has to manually reset the value on the platform to restart the water flow.

The water quality monitoring unit will consist of a pH sensor and an in-house fabricated circuit for reading the total dissolved solids (TDS) of tap water. These sensors will collect analog inputs and further deliver them to the Arduino Uno development board which will analyze the same and perform programmed operations based on the permissible limits of the measured parameters.

4.1 Functional Requirement –

The development of water quality detection systems using IoT (Internet of Things) mainly focuses on creating a more ideal & portable system at a relatively reasonable cost. With the same intentions, developers propose to use an Uno R3 CH340G ATmega328P-U-TH Development Board compatible with Arduino instead of the conventional Arduino Uno R3 which contains an ATmega16U2. The inexpensive CH340 chip, as compared to the original R3 boards, has its own advantages and disadvantages. One major advantage being about its efficient power consumption performance. As published by Joshua Hrisko in his article on makersportal.com [8], experimental results confirmed that the CH340 board was much more efficient than the R3 board universally.

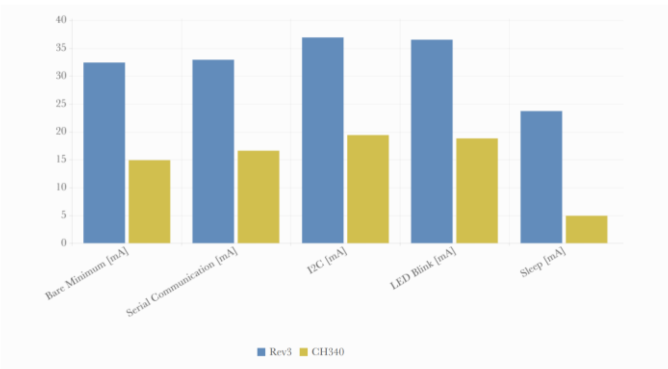

Chart -1: Measurement of Current Consumption R3 vs CH340 Uno

He also concluded that the CH340, which is often considered a poor alternative to Uno R3, is in actual nearly as fast at uploading sketches, is more efficient than R3 and runs at almost the same speed when computing. The only drawback to CH340 is its incompatibility with MacOS, which won’t be in the picture for the developers as they will be operating on Windows OS. Hence, based on the following analytical and experimental conclusions the developers decided to minimize the cost by investing into the more power efficient and cheaper, CH340 board.

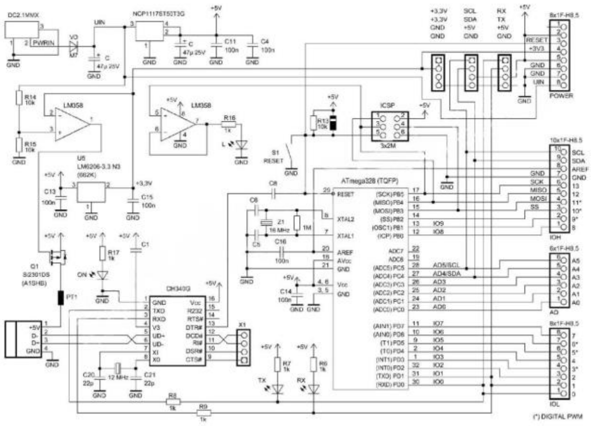

Fig -3: Schematic Circuit Diagram for Uno R3 CH340G ATmega328P

In order to establish communication between the server and microcontroller, the proposed system also must connect to a network. To do so, the developers will be using a ESP8266 Serial WiFi Wireless Transceiver Module that can give the microcontroller access to the users personal WiFi network and hence justifying the definition of IoT enabled system. The ESP8266 module is preprogrammed with an AT command set firmware hence making it the best cost-effective choice for the system.

4.2 Hardware Requirement –

The proposed system involves monitoring of two water parameters which are considered to be one of the major contributing parameters towards the quality of water along with the net volume flow of water through the tap. The quality monitoring is proposed to be done with the help of relevant sensors for pH value and TDS value of tap water individually whereas the water management will be done with the help of a Water Flow Measurement Sensor and an electrically operated Solenoid Valve.

A pH Sensor helps to measure the acidity or alkalinity of the water. The pH scale is a logarithmic scale whose range is from 0-14 with a neutral point being 7. Values above 7 indicate a basic or alkaline solution and values below 7 would indicate an acidic solution. The developers propose to use a Grove-pH Sensor manufactured by SeeedStudio. It operates on both 3.3V and 5V power supply and it is easy to interface with Arduino. For the pH sensor to be accurate, the developers will be properly calibrating the sensor time to time and hence, will also be concluding the range of accurate and reliable results over the time. Hence, before being installed, the electrode will be calibrated with a standard buffer solution of known pH value.

Fig -4: SeeedStudio Grove pH Sensor Kit (E201C)

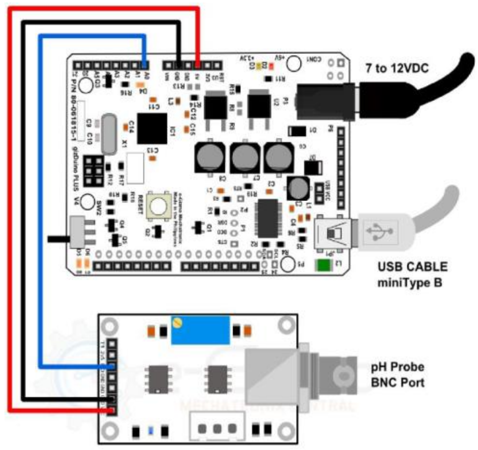

Fig -5: Sample Connections for pH Sensor

[Source: Datasheet pH Sensor E-201-C by e-Gizmo Mechatronix Central]

TDS (Total Dissolved Solids) indicates the matter of soluble solids (in milligrams) that are dissolved in a single litre of water. By and large, the higher the TDS value, the more soluble solids are dissolved in water, and the less clean the water is. Therefore, the TDS value can be used as one reference factor for reflecting the cleanliness of the water. This can be implemented to domestic water, hydroponic and other fields of water quality testing and monitoring. Normally, we use a TDS pen or compatible sensors to measure the TDS of water. However, the developers have decided to do this project without the use of the TDS sensor or pen. They propose to develop and fabricate a circuit in-house for the purpose of TDS monitoring. The working of the same is based on the very simple definition of TDS and its basic properties. The developers will calculate the resistance of the tap water and from that, they will obtain the resistivity of the same. They also have to consider the length and the cross-sectional area of the specific pipe section for this. From the obtained resistivity, the developers can further analyze for the conductivity and hence thereafter the TDS from the conductivity of the tap water.

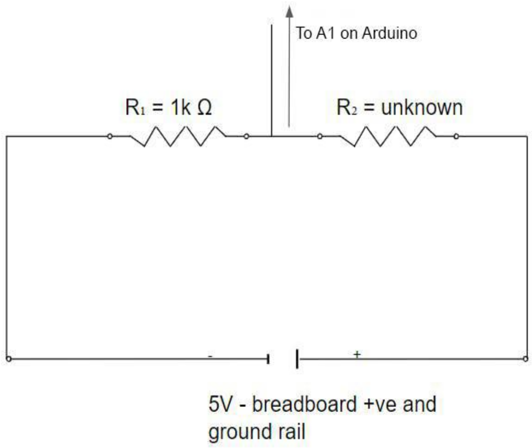

Fig -6: Schematic Diagram for TDS Circuit

Water flow sensors are installed at the water source or pipes to measure the rate of flow of water and calculate the amount of water flowing through the pipe in a certain time. Rate of flow of water is measured as litres per hour or cubic meters. The developers propose to use a YF-S201 Water Flow meter Measurement Sensor with 1-30Leter/min Flow Rate. This sensor sits in accordance with the inlet of the proposed system and contains a pinwheel sensor to gauge the flow of liquid through it. It is incorporated with a magnetic hall effect sensor that yields an electrical pulse with every revolution. The hall effect sensor is sealed from the water pipe and permits the sensor to remain dry and protected. Hence, the main working principle of this sensor is the Hall Effect. As stated by this principle, in this sensor, a voltage difference is induced in the conductor because of the rotational motion of rotor. When the pinwheel is rotated because of the progression of water through the sensor, it pivots the rotor which induces the voltage. This induced voltage is measured by the hall effect sensor and the stream flow rate and volume of water stream is determined.

Fig -7: YF-S201 Water Flow Measurement Sensor

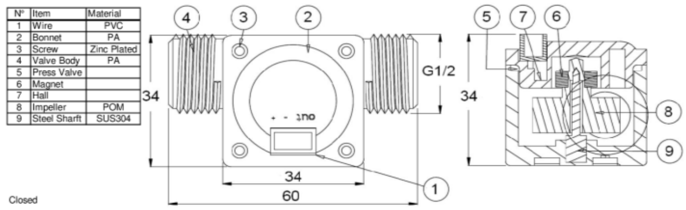

Fig -8: Layout - YF-S201 Water Flow Measurement Sensor

A solenoid valve is used in the proposed system to regulate the flow of water through the tap and help its management by avoiding over utilization and water loss. The developers will be using a 24V DC Solenoid Water Valve Switch of diameter 1/2″ which will control the flow of water. Normally, the valve is closed and it opens for the flow of water as soon as it receives a 12V DC Supply via the microcontroller. When the set limit for the flow of water through the tap is reached the microcontroller cuts off the supply and hence the valve returns back to closed state blocking the flow of water which results in the tap running dry.

Fig -9: YF-S201 Water Flow Measurement Sensor

4.3 Software Requirement –

The proposed system will be based on the analytics server, ThingSpeak, which is an Open-Source IoT Application and API allows user to store and recover information from Hardware devices and Sensors and further enable third-party to read the same. It involves HTTP Protocol over the Internet or LAN for its correspondence. The MATLAB analytics is incorporated to dissect and visualize the information received from the Hardware or Sensor Devices. It supports creating channels for every single sensor data we wish to collect. These channels can be set as private channels or can share the information freely through Public channels. The commercial features include additional features, but the developers will be using the free version as they are doing it for educational purposes and no additional requirements.

The Thingspeak application will help the developers in connecting and collecting the data from the sensors in private channels and then further in visualizing and analyzing the received data in MATLAB. The application also enables sharing the data collected to the worldwide community or further transfer the data to a third-party application with the option of public channels. The application also has REST API and MQTT APIS which is helpful in communications.

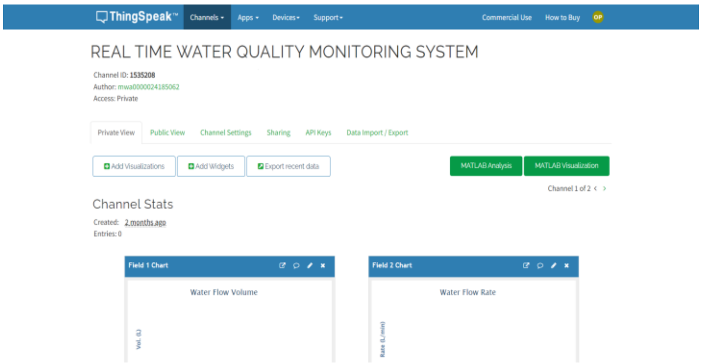

Fig -10: Thingspeak Dashboard Preview

4.4 Breadboard Model –

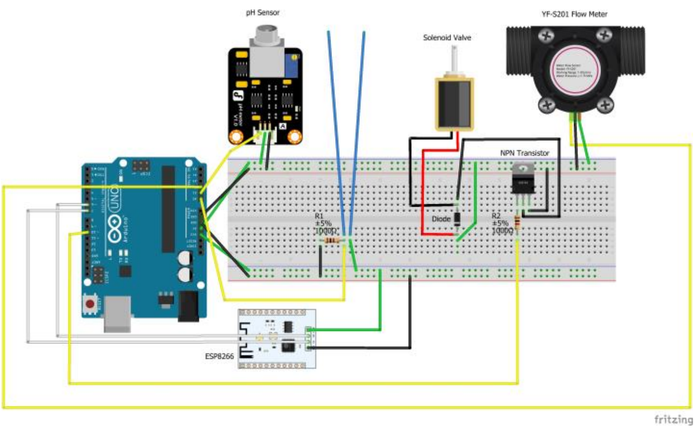

Fig -11: Breadboard Modelling of the Proposed System

4.5 Schematic Diagram –

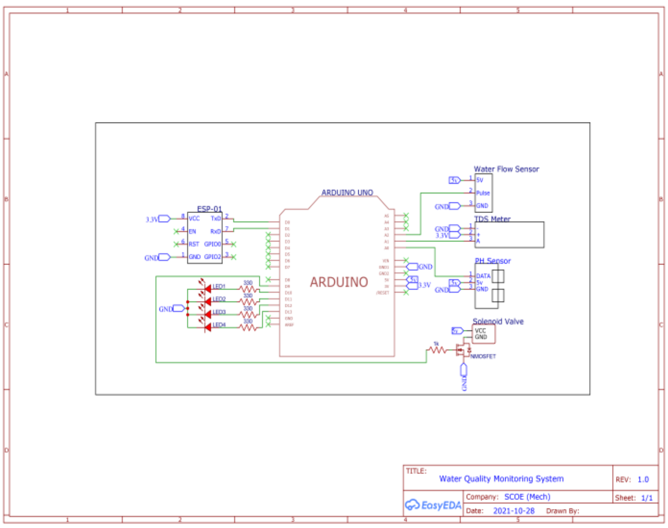

Fig -12: Schematic Diagram of the Proposed System

5. METHODOLOGY

The Real Time Water Quality Monitoring & Management System operates in five steps. The below steps are involved as power is supplied to the system.

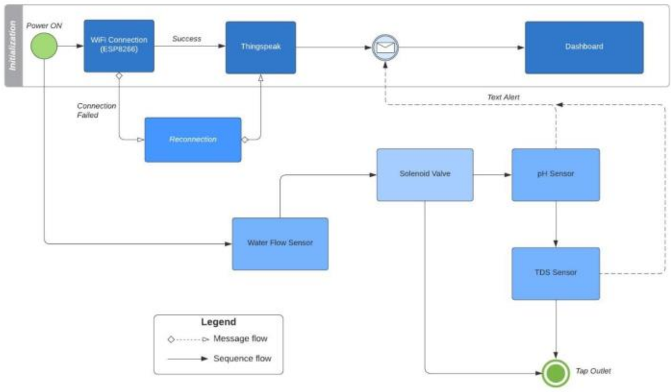

Chart -2: Flow Chart of the Proposed System

5.1 Initialization –

For the very first operation of the installed system, the user has to provide WiFi access to the system by manually typing in the SSID & Password. This will allow the system to connect to its cloud server and hence, allow the user to access data remotely anytime with the help of ESP8266 Module. Users have to follow the procedure to connect the system to their Personal Wifi,

Step 1: For first initialization, enter the below details manually

WiFi SSID & WiFi Password

Step 2: Wait until the system establishes a secure connection with the WiFi

Step 3: If the system fails to connect, try connecting to another WiFi or re-input the credentials and make sure that these are case sensitive.

Step 4: System establishes a secure connection and then it will automatically connect to the cloud server.

After the first setup is completed, whenever the system is powered on, the system will automatically connect to the WiFi and hence will carry out the initialization process automatically and establish connection with the cloud server in no time.

5.2 Measure of Water Flow –

As the tap is opened, water first flows through the YF-S201 Water Flow Measurement Sensor which measures the flow rate and volume of flow and then further converts it to corresponding analog signal. The main working principle behind the working of this sensor is the Hall effect. As stated by this principle, in this sensor, a voltage difference is induced in the conductor because of the rotational motion of rotor. When the pinwheel is rotated because of the progression of water through the sensor, it pivots the rotor which induces the voltage. This induced voltage is measured by the hall effect sensor and the stream flow rate and volume of water stream is determined.

The obtained analog signal acts as input for the microcontroller, which then processes and analyses the signal and carries out certain calculations to finally provide an output of water flow rate in L/min and total volume in Litres. This obtained output is then sent over to cloud server, Thingspeak with the help of established WiFi connection using ESP8266. With the help of MATLAB, the data is visually represented and the microcontroller is programmed with a defined value of volume of water flow, which when crossed, triggers and alerts the user and stops the flow of water with the help of a solenoid valve.

5.3 Flow of Water through Solenoid Valve –

After the water passes through the Water Flow Sensor, it then has to pass through a solenoid valve which is responsible for managing the flow of water to prevent excessive usage and wastage. Normally, the valve is closed and it opens for the flow of water as soon as it receives a 12V DC Supply via the microcontroller. As the Arduino is powered ON, the default command set for Solenoid Valve is HIGH, hence it immediately opens for the flow of water.

When the set limit for the flow of water through the tap is reached the microcontroller cuts off the supply, meaning that the command set is LOW, and hence the valve returns back to closed state blocking the flow of water which results in the tap running dry.

5.4 Measure of pH parameter of water –

The water then diverges into two streams one directly leading to output, while the other passes through a series of sensors for accessing the quality of water. At first, the calibrated pH sensor measures the hydrogen-ion activity in water-based solutions, which is then used to calculate the pH value of water.

The pH sensor sends analog signals to the microcontroller which reads the voltage, sampling time and sampling interval from the sensor. Based on the following inputs, the microcontroller is then programmed to carry out a series of calculations to determine the average pH value of the flowing tap water. The obtained pH value is then shared to the cloud server, Thingspeak, which with the help of MATLAB Programming visualizes the data into graphical format.

5.5 Measure of TDS parameter of water –

The water, after passing through the pH sensor, flows through a section, across which it's Voltage is measured with reference to the calculated theoretical value. This voltage acts as an analog input for the microcontroller, which is programmed to calculate the resistivity of the flowing water with the help of the same. The obtained resistivity is then converted to conductivity in mS/cm. Finally, the conductivity is used to calculate the TDS value of tap water. Based on the obtained values, the numerical calculations will be,

$$R = r * (L/A)$$

$$\Rightarrow r = R * (A/L)$$

where,

r= Resistivity [*ohm-cm*]

R= Radius of pipe [*cm*]

L= Length of pipe section [*cm*]

A= Cross-sectional area of pipe section [*cm*2]

$$\sigma = 1/\, r$$

$$\boldsymbol{TDS = \sigma * 700}$$

where,

σ= Conductivity [*milliSiemens/cm*]

r= Resistivity

TDS= Total Dissolved Solids [*parts per million*]

The final TDS value is then shared to the cloud server and visually represented for the user.

5.6 Analysing the quality of water –

Based on the inputs received, the microcontroller analyses the parameters of the tap water by comparing it with standard WHO valves of potable water of the same. If the water quality is found to be satisfactory the LED's light up to Green, but if the quality of water is not satisfactory yet in the permissible limits the LED's light up to Orange. If the quality of water is found to be very poor than the specified limits, the LED's light up to Red, which indicates to the user that the water is not potable.

6. EXPERIMENTATION

The proposed model intends to increase the efficiency of water quality monitoring system as well as help management of this natural resource. In addition, the real time monitoring and management control helps ease the process of quality assessment and also limits the human error. The developers carried out static testing of the prototype in order to validate the idea by collecting data and analyze it.

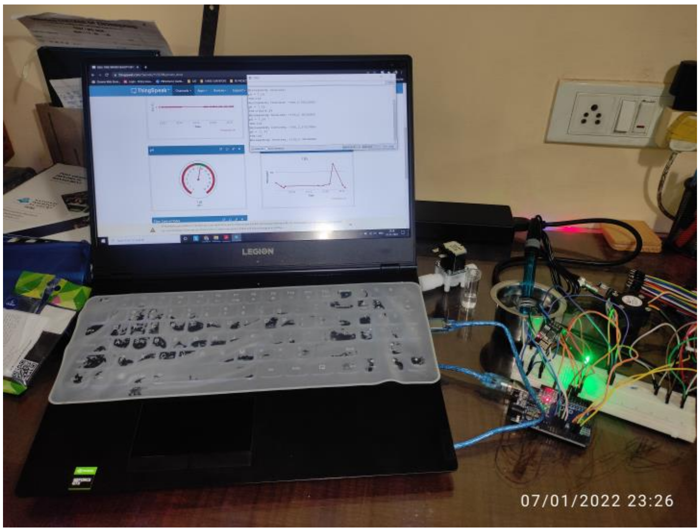

Fig -13: Static Assembly & Testing of the Proposed System

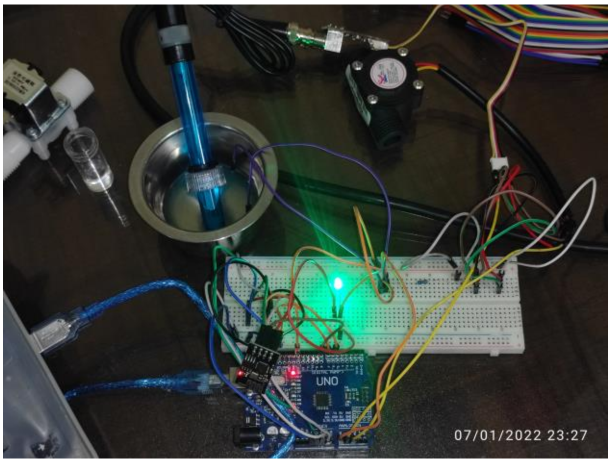

Fig -13: Physical Connections of the Proposed System

7. CONCLUSIONS

The proposed Real Time Water Quality Monitoring & Management System aims to advance the conventional method of testing water quality at labs and scaling them down to household levels. In addition to monitoring the water quality parameters the system also helps in efficient management of the same hence not only helping to avoid any water borne diseases but also as help in limiting the use of this natural resource.

The developers also implemented and experimented an in-house developed TDS measuring circuit which is based on the simple principle of conductivity of water and its correlation with TDS. The proposed system is developed to fit in a larger perspective of smart buildings in the coming years of Smart City and Industry 4.0 generation. Although, the same has its own restrictions and limitations which can be improvised with time and advancements.

8. FUTURE SCOPE

As discussed, the implementation of the proposed system is to enable the water management system to be autonomously driven, hence leading to a smart building. In addition, while the scope of this project is limited to the well-developed and metropolitan cities, with advancements the system can also be further developed as a low cost and more portable to spread widely in different areas of interest.

Similarly, the proposed system can be further modified to take care of purification if the quality of water is found to be unsatisfactory. The developers also put forward an idea of implementing Machine Learning in the same proposed system, hence enabling it to forecast the quality of water and assure the consumer about its quality directly.

Also, with certain constraints, the proposed system is only limited to monitoring pH and TDS parameters of water quality. Other parameters such as salt contents, oxygen levels, microbes etc. can also be monitored with addition of more technology.

ACKNOWLEDGEMENT

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BIOGRAPHIES

Omkar Pharande is a Final Year student of Bachelor's in Mechanical Engineering. With strong technical foundations, he has an inclination towards the AI & Automation future and wishes to gain deeper insights to financial world and excel in the same by learning, contributing and applying his skills.

Sanket Patil is a Final year student of bachelor's in mechanical engineering. He is interested in learning new skills and has knowledge about core mechanical subjects.

Sourav Burse currently pursuing final year of Bachelors of engineering degree in mechanical engineering and with strong technical knowledge he has an interest towards the field of Cloud Computing and its services and wishes to gain deeper insights in the technologies like amazon web services (AWS), Microsoft Azure and Google Cloud and excel in the same by learning, contributing and applying his skills.

Rutuja patil is a Final Year student of Bachelor's in Mechanical Engineering. With strong technical skills, wishes to gain deeper knowledge in technical field. By learning, contributing and applying her skills.